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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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VOL. CVII.—No. 2784.] *LONDON: FRIDAY, MAY 9, 1919.* [*Registered at the General Post Office as a Newspaper.*] PRICE 9d. BY INLAND POST ... 11d.

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See page 17. 7363
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See half-page Advertisement page 95, April 18.

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II.—LABOUR ADMINISTRATION.
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III.—FACTORY ACCOUNTING.
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DISCUSSION WILL FOLLOW EACH LECTURE.

Particulars, on application by post, to—
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U 700

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A Competitive Examination for not less than one POST as PROBATIONARY ASSISTANT CONSTRUCTOR will be held at the Royal Naval College, Greenwich, towards the end of June next.
The Regulations and full particulars of the salary, prospects of promotion, etc., may be obtained from the SECRETARY (C.B.), ADMIRALTY, Great George Street, S.W. 1, to whom intending candidates must submit their names and full particulars of their educational and technical training and practical experience not later than 15th May next.

PRIVATE STUDENTS OF NAVAL ARCHITECTURE.

In conjunction with the above examination, there will be a qualifying examination for the Admission of Private Students of Naval Architecture to the Royal Naval College, Greenwich. Applications for the regulations, etc., should be made as in the case of the examinations for the post of Probationary Assistant Constructors (see above).
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(i) About 2000 tons of STANDARD STEEL GIRDER TRAMWAY TRACK RAILS with FASTENINGS, and
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Persons desiring to submit Tenders may, on and after TUESDAY, 13th inst., obtain the Drawings, Specification, Bills of Quantities, Form of Tender, and other particulars on application to the CHIEF ENGINEER of the Council, County Hall, Spring Gardens, S.W., upon payment to the Cashier of the Council of the sum of £2. This amount will only be returned if a *bona fide* Tender is submitted. Full particulars may be obtained on application at the County Hall previously to the payment of this fee.
The Contractor will be bound to pay to all employees employed by him in and about the execution of the Contract, or any part thereof, wages at rates not less, and to observe hours of labour not greater than the rates and hours set out in the Council's list, and such rates of wages and hours of labour will be inserted in and form part of the Contract by way of Schedule. Full particulars of the Council's Standing Orders on these matters are given in the *London County Council Gazette*. No Tender received after One p.m., on Tuesday, 27th May, 1919, will be considered. The Council does not bind itself to accept any Tender.
JAMES BIRD,
Clerk of the London County Council. U 706

THE CHARING CROSS, WEST END & CITY ELECTRICITY SUPPLY COMPANY, LTD., invite

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PLANT, which must be disposed of quickly in order to make room for larger units. Two T.C.T. 9 Standard Bellies & Morcom Self-lubricating Triple Expansion Condensing ENGINES, H.P. Cylinder, 12 in.; Intermediate, 26 in.; L.P., 43 in. Stroke, 20 in.; Revs., 230; Steam Pressure, 150 lbs
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G. R.

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24 HYDRAULIC PRESSES, together with Two Three-throw Pumps, Accumulators, &c., now lying in the Midlands and Northern Counties.

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Tenders are Invited for Various

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For Sale by Tender this

FREEHOLD FACTORY.

The following is a brief description:—
Situation.—Fronting Main Road and Electric Tram Route from Sheffield to Rotherham.
Within the City of Sheffield, ¾ mile of Tinsley Station, G.C. Ry.
Construction.—The Main Engineering Shop is steel framed with corrugated iron walls, roof part glazed and part corrugated iron. Floor of wood and concrete; length 580 feet, width 400 feet, height 20 feet in the clear. Electric cranes either side of building, area, 234,000 super feet.
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Canteen and Lavatories, area 26,833 super feet.
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The Factory was erected by the Government in 1915-16, and has been used for Shell Making.
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Sidings.—Full gauge connection with the G.C. Railway. Total length 4565 feet.
Office Accommodation for 209 clerks.
Mess Room Accommodation for 1500 persons.
Forms of Tender may be obtained from the DISPOSAL BOARD, Factories Section, Charing Cross Buildings, Embankment, London, W.C. 2. U 693

G. R.

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TWO SINGLE-LIFT GASHOLDERS & TANKS AT R.N. AIR STATION, KINGSNORTH.

For Sale by Public Tender.

TWO Single-Lift Spiral Guided GASHOLDERS—
40 ft. 0 in. diam. × 16 ft. 9 in. deep.
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41 ft. 6 in. diam. × 17 ft. 0 in. deep.
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Tender Forms and permits to view can be obtained on application to the CONTROLLER, Machinery and Plant (Demobilization), Charing Cross Buildings, London, W.C. 2. U 590

TO ENGINEERS, MACHINE TOOL MAKERS, IRONFOUNDERS, AND OTHERS.

An Unique Opportunity is

afforded to persons possessing a small capital, of ACQUIRING as a GOING CONCERN, the PROGRESSIVE and VALUABLE BUSINESS of Engineers, Founders, Machinists, &c., carried on by the CHURNET VALLEY ENGINEERING Co., Ltd., Leek, since 1910, and satisfactory reasons can be given for disposal.
The Works, which are extensive and commodious, are replete with modern and valuable machinery. The premises are well built and in excellent repair. The premises, including the Fixed Plant and Machinery, are held by the Company at a reasonable rent, and have Railway and Canal accommodation within easy accessibility. The Machinery is electrically driven, the Works being lit throughout by Electric Light. The town of Leek is situate 12 miles from Stoke-on-Trent, which is itself the centre of a large manufacturing and industrial area. A good business has been done, and the Company has a high reputation for its 6½ in. centre Lathes and Sud Pumps.
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Every facility will be given to those desirous of forming a new Company, and the undertaking can be purchased, including the freehold Works, for a sum of about £16,000, exclusive of the Book Debts, which can, however, be taken too if desired.
To view and for further particulars, apply to G. H. HAY, Chartered Accountant, 50, St. Edward Street, Leek, or G. G. POPPLETON, Chartered Accountant, 36, Corporation Street, Birmingham, Joint Liquidators, to whom Tenders should be delivered not later than Ten a.m., on Wednesday, the 14th day of May next ensuing. Neither the highest nor any Tender will necessarily be accepted. U 484

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Recovered Screws and

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About 14 tons Steel Screws, mostly ready for use, 3/16 in. to ½ in. Gauge, assorted sizes.
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Applications should state Reference D.D. 8/A/Group/98. U 701

APPOINTMENTS OPEN.

DERBY COUNTY ASYLUM, MICKLEOVER, NEAR DERBY.

The Committee of Visitors Invite

Applications for the Post of

RESIDENT ENGINEER.
Candidates to have institution experience, and a thorough knowledge of electric light installation, heating, and the general building trade, and able to supervise the Works Department of the Asylum.
Salary £175 per annum, with House, Coal, Gas and Garden, subject to the provisions of the Asylum Officers' Superannuation Act.
Applications, stating age, qualifications and experience, with not more than three recent testimonials, must be marked "Resident Engineer," and sent in, addressed to the undersigned, not later than 19th May, 1919.
N. J. HUGHES HALLETT,
Clerk to Asylum Committee.
County Offices,
St. Mary's Gate,
Derby. U 586

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FREDK. HORNER,
Secretary.
Education Dept.,
Council House, Coventry,
29th April, 1919. U 685

CITY OF COVENTRY.

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Applications are Invited for

the Appointment of CIVIL ENGINEERING DRAUGHTSMAN, with first-class experience in constructional work.
Salary £4 4s. per week.
Applications, stating age, qualifications and experience, together with copies of three recent testimonials, to be sent to the undersigned on or before the 16th May, 1919.
T. R. WHITEHEAD,
General Manager and Engineer.
Tramway Depot,
Priestley's Bridge,
Coventry. U 670

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MUNICIPAL TECHNICAL COLLEGE.
Principal—J. CROWTHER, B.Sc. (Lond.).

Applications are Invited for

the following POSITIONS:—
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3.—Assistant in the Mechanical Engineering Department.
Salaries of (2) and (3) £200-£250 per annum, according to qualifications and experience.
4.—Assistant Master in the Junior Technical School. Salary according to scale.
Particulars and forms of application, to be returned as early as possible, may be obtained from the Principal. U 682
W. H. OSTLER,
Secretary.

ASSISTANT ENGINEER.

THE METROPOLITAN ASYLUMS BOARD invite

Applications for the Appoint-

MENT of ASSISTANT ENGINEER on their Head Office Staff.
Applicants should be of good education and be well trained and qualified mechanical and electrical engineers who have served their time with first-class engineering firms. They should have good theoretical scientific and engineering knowledge, attested by scientific or engineering degrees, and should also have had experience in purchasing coals on their calorific values.
The Candidate appointed will be responsible for the general supervision and economical working and upkeep of a large number of steam boilers, steam engines, deep well pumping plants and heating and hot water supplies; and of laundry and kitchen machinery and appliances.
Salary £400 per annum, rising by £25 annually to £500.
Application forms can be obtained from the Office of the Board and must be returned, accompanied by copies of testimonials, on or before 30th May, 1919. Envelopes to be endorsed, "Application for Assistant Engineer."
DUNCOMBE MANN,
Clerk to the Board.
Embankment, E.C. 4. U 696

STAFFORDSHIRE EDUCATION COMMITTEE.

COUNTY METALLURGICAL AND ENGINEERING INSTITUTE, WEDNESBURY.

The Staffordshire Education Committee REQUIRE the

Services of an Assistan

LECTURER in Engineering Subjects in connection with the above-named Institute.
A commencing salary of £250 to £300 is offered.
Candidates must be qualified to give class-room and laboratory instruction in Mechanical Engineering and related subjects. Acquaintance with Elementary Electrical Engineering and works experience is desirable.
Further particulars and forms of application may be obtained from the undersigned. Applications must be received not later than Saturday, 31st May, 1919.
GRAHAM RALFOUR, Director of Education.
County Education Offices, Stafford,
May, 1919. U 5[illegible]

INDIAN PUBLIC WORKS AND STATE RAILWAY DEPARTMENTS.

THE SECRETARY OF STATE FOR INDIA IN COUNCIL will in 1919

Appoint 75 European

and 2 INDIANS as ASSISTANT ENGINEERS in the INDIAN PUBLIC WORKS AND STATE RAILWAY DEPARTMENTS, if so many suitable candidates present themselves.
Every candidate must be a British subject, or a ruler or subject of any State in India in respect of whom the Governor-General of India in Council has made a declaration that he is to be considered eligible.
The appointments for Europeans will be reserved for candidates who have served in His Majesty's Forces during the war for at least one year, or who have been prevented on adequate grounds from serving. European candidates must have been born on or after 2nd August, 1891 and on or before 1st August, 1897.
Indian candidates must have attained the age of 21 and not attained the age of 24 years on 1st July, 1919.
Every candidate must either (1) have obtained one of certain recognised University degrees or (2) have passed certain distinctions in Engineering, or (3) have passed Sections A and B of the Associated Members Examination of the Institution of Civil Engineers, or have been exempted by the Institution from examination, or (3) produce the required evidence that he is otherwise eligible under the Regulations.
Applications from European candidates must reach the India Office by 31st March, 30th June, and 30th September for the three sittings respectively of the Selection Committee, which will be held in April or May, July or August, and October or November. Applications from Indian candidates must reach the India Office not later than 30th June. Printed forms, together with information regarding the conditions of appointment, may be obtained from the SECRETARY, Public Works Department, India Office, Whitehall, London, S.W. 1.
India Office, London,
February, 1919.

COLLOIDAL MATTER.

A FEW decades ago colloidal matter, not more than sixty years old altogether, hardly interested more than a small group of specialists. Of late, people have been told that colloids are not merely most potent factors in all matters biological, but that they have also an important bearing on a vast range of technical processes, metallurgical not excepted, and that almost any substance, common salt as well as glue, can by subdivision be obtained in the colloidal state. If, then, it be merely a question of subdivision why single out colloids as a special class, and why create a confusing number of new terms, like dispersoids, suspensoids, emulsoids, gels, sols, protective colloids? That there are good reasons for these distinctions, and that the technical student, quite apart from the scientist, would do well to acquaint himself with them, Professor Alexander Findlay, D.Sc., F.I.C., clearly demonstrated in two lectures on "Colloidal Matter and its Properties," which he delivered at the Royal Institution on April the 3rd and 10th last.

Professor Findlay first showed the difference between a real solution and a colloidal solution. When aqueous solutions of copper sulphate and of ammonia were mixed, a clear dark blue solution was produced. A mixture of yellow prussiate of potassium and ferric chloride, both in aqueous solution, seemed likewise to yield a homogeneous dark blue solution of molecules uniformly distributed throughout the liquid. But when the two solutions were poured on a jelly of gelatine, the copper-blue soaked down into the jelly, the prussian blue did not. The experiments were akin to the historical experiments of Thomas Graham, about 1860, that some substances, which he called "crystalloids," were able to diffuse through membranes, whilst others, the "colloids," would not diffuse through his dialyser. Graham's definition had its practical value; but subsequent researches showed that even colloids might pass through ordinary membranes, and yet be separated into larger and smaller particles or molecular aggregates by the aid of membranes of collodion and other means, and that we should speak of a colloidal state of matter rather than of colloids. Nearly all substances might be obtained in a fine dispersoid condition; certain properties, Dr. Findlay explained, admitted of distinguishing between suspensoids, suspensions of small particles (clay, *e.g.*), in water or some other medium in which they were not soluble; and emulsoids, emulsions of oil, *e.g.*, in some medium in which they were at any rate partly soluble or muscible with it.

When arsenious acid was treated with sulphuretted, hydrogen a yellowish liquid was produced which looked homogeneous under the microscope, but which the ultramicroscope of Siedentopf and Zsigmondy proved to be heterogeneous. In this ultramicroscope the Tyndall beam of light—invisible as such in a dust-free medium—was sent horizontally through the solution, at right angles to the direction in which the observer looked. Particles of 6 $\mu\ \mu$ (1 micron $\mu = 0{\cdot}001$ mm.; 1 millimicron $\mu\mu = 0{\cdot}001\ \mu$ or one-millionth millimetre) could thus be detected, though not actually be outlined—what was observed was really a diffraction effect. Suspensoids could be produced by mechanical subdivision of solids or liquids, or by precipitation. Dr. Findlay exemplified the former by the method of Bredig. He dipped two wires of silver, joined to a 110-volt circuit, into water, and brought the wires into contact; a succession of greenish light flashes was seen, and the water turned brown with colloidal silver. A peculiar ruby-red solution of gold has long been known. Dr. Findlay showed Faraday's pink solution, prepared by reducing gold chloride with phosphorus, which had kept clear in the Royal Institution for sixty years, and demonstrated the method by adding tannic acid to a very weak solution of gold chloride; the colourless mixture turned pink on heating and ruby-red on adding another drop of gold chloride to it. Colloidal gold could also be obtained in other colours, the sizes of the particles in $\mu\ \mu$ being (Zsigmondy): Rose 6, bright red 10 to 17, violet 23 to 32, purple 33, violet and blue suspensions 45 to 130 $\mu\ \mu$; the colour did not depend upon size alone, however. Ruby glass had been made in the Middle Ages by dissolving gold in fused glass; cooled rapidly, that glass looked yellow; when heated too strongly, on the other hand, the particles aggregated and turned blue.* Similar colour differences were obtained by the aid of metals in the toning of photographs, and colloidal metals were widely utilised further for their bacteriocidal and general therapeutical action.

All colloidal particles assume electric charges when mixed with liquids. In water ferric hydrate becomes electropositive, arsenious sulphide negative, and the particles travel, therefore, under a potential gradient, either to the cathode or to the anode; at the electrodes they give up their electric charges and agglomerate, whilst before that the mutual repulsion had kept the particles apart and prevented their settling, sometimes for years. Coarse clay stirred into water, Dr. Findlay demonstrated, soon settled again. When he dipped a copper and a zinc electrode (battery terminals) into the suspension, however, the fine clay mud adhered to the zinc, and in this way kaolin, which became positively charged when dispersed in water, was in Germany sifted for porcelain manufacture by kataphoresis. By the same process—sometimes called electro-osmosis, though that name had an additional meaning—peat and many other substances were deprived of part of the water which all colloids retained tenaciously. Very little current was consumed in this dehydration; the establishment of a potential difference seemed sufficient, and that was commercially important; the peat drying (of the late Botho von Schwerin) did not appear to be successful, however. Since now some colloids carried positive charges, and some negative, the mixing of the oppositely charged ferric hydrate and arsenious sulphide, *e.g.*, neutralised the charges, and such colloids precipitated one another. Dr. Findlay illustrated this in another way. Three small dishes were placed on the table; the first contained a solution of night blue, a positive colloid, the second Congo red (negative), the third alkali blue (negative); a strip of filter paper was suspended over each dish so as just to dip into the liquid. The bright blue did not rise in the paper, the colour remaining limited to the lower edge of the paper where the positive charge of the blue and the negative charge of the paper (itself a negative colloid) neutralised one another; this dye was therefore precipitated as soon as it came in contact with the paper, and the water alone rose by capillary attraction between the fibres of the paper. In the other two cases there was nothing to prevent the capillary ascent, and the dyes therefore rose to considerable heights, especially the alkali blue. As now wool, cotton and silk were all of colloidal nature, some dyes directly adhered to these materials—though this was not the whole explanation of the dyeing process. We could further neutralise, and hence coagulate and precipitate, colloidal solutions by adding electrolytes to them, which dissociated into charged ions; thus hydrochloric acid turned the pink gold solution blue by the coagulation of the small pink particles into larger blue particles. In this precipitation ions carrying more than one charge were, as Hardy first showed, much more powerful than ions with one charge. Owing to this action by the ionised salts of sea water the fine mud which was suspended in rivers was precipitated in the estuaries, leading to the formation of bars and deltas.

Passing to emulsoids, Dr. Findlay remarked that their visibility by the ultramicroscope was largely due to differences in the refractive index of the albuminoid, gelatin, starch, &c., and of the water in which they were suspended. Emulsoids were not precipitated by electrolytes, except by concentrated electrolytes; but the process of gelatinisation was much altered by the presence of electrolytes, and it was in this case the negative ion which seemed most active, whilst in the previously-mentioned precipitation of suspensoids the positive ion (the metal) seemed chiefly to be concerned. In the presence of alkali sulphate, *e.g.*, the temperature at which a gelatinous solution turned into a gel (a jelly) was raised; citrates and tartrates behaved like sulphates, but chlorides, iodides, &c., lowered the temperature, so that a jelly would not set in the presence of iodides. The gelatinisation process was reversible; we were dealing with two liquids partly soluble in one another, and water might be taken up or separated out. In plant growth this imbibition of water was of great importance. Seaweed took up water to the amount of 330 times the volume of air-dry substance when at a pressure of 1 atmosphere, 96 volumes at 7 atmospheres, and 16 volumes at 41 atmospheres; the retention of the water by the cells prevented the drying up of the plant, and enabled the sap to rise, and the soil retained its water with the aid of the colloids in the soil. Electrolytes again played a part in this imbibition, increasing it (acids in low concentrations) or decreasing it; the gelatine of the photographic film hard with the silver from the bromide did not take up water.

The fact that diluted electrolytes, as distinct from concentrated electrolytes, diffused into jellies and were adsorbed by them accounted for the Liesegang phenomenon. When gelatine was soaked with potassium dichromate solution and a drop of silver nitrate was made to fall on the jelly, a brown spot of silver dichromate formed and surrounded itself with a system of dark rings at increasing distances; the delicate markings of agate were due to the same cause, the hydrated silica forming the jelly in this case. Since further emulsoids were not precipitated by diluted electrolytes, suspensoids were rendered more stable by the addition of emulsoids. When silver nitrate was mixed with sodium chloride (or bromide) in aqueous solution, the well-known white precipitate of curly silver chloride was formed; when the salt contained gelatine in solution, however, the silver chloride remained colloidal, uniformly dispersed in the translucent solution, whilst a precipitation did not take place. Without that dispersion, gelatin films could not be used for photography, because the curly precipitate would give a badly patchy image. This protective power of emulsoids recorded itself in another way. When we precipitated a suspensoid by an electrolyte, the coagulum would not redissolve again on removing the electrolyte; but if we added a small amount ($\frac{1}{2}$ per cent.) of soda to china clay, the clay was "peptised" or "peptonised" and remained for a long time in colloidal suspension; the particles could afterwards be separated by kataphoresis when wanted. In Acheson's lubricating graphite (oildag and aquedag) ground up graphite was peptonised in oil or water with the aid of a little tannic acid. Dr. Findlay finally referred to the large surface development of colloids which rendered them powerful as adsorbents. Although, he remarked in conclusion, colloids had first been studied by Graham in University College, London, the further scientific and technical development had, as in many other branches, largely been left to Germany, and it was only lately that the study of colloids had received due and noteworthy attention again in this country.

* The germ method of Zsigmondy gives gold particles of definite sizes, which is technically important.

BROWN-BOVERI LOCOMOTIVES FOR THE SWISS FEDERAL RAILWAYS.

By J. BUCHI, Chief Engineer, Locomotive Department, Baden Works.

(*Concluded from page* 565.)

THE test locomotive mentioned in the first part of this article is actually in regular service on the Loetschberg line, and is equipped for experimental purposes with two individual axle drives. These have been designed on quite a new principle, and it may be assumed that a short description of such a driving arrangement will be of interest, especially in railway circles. Although for steam locomotives and for automobiles a certain recognised type has been reached after years of development from the numberless forms proposed and tried, such a stage has not yet been attained with electric locomotives. Here especially the question of single or multiple driving systems has not been thrashed out. In America the driving axles have been provided almost without exception with individual motors, either geared to or directly mounted on the axles, while in Europe we have not been able to free ourselves

ELECTRIC LOCOMOTIVE WITH SINGLE AXLE DRIVES.

CONSTRUCTED BY MESSRS. BROWN, BOVERI AND CO., ENGINEERS, BADEN, SWITZERLAND.

SINGLE AXLE DRIVE, TSCHANZS SYSTEM.

Fig. 13

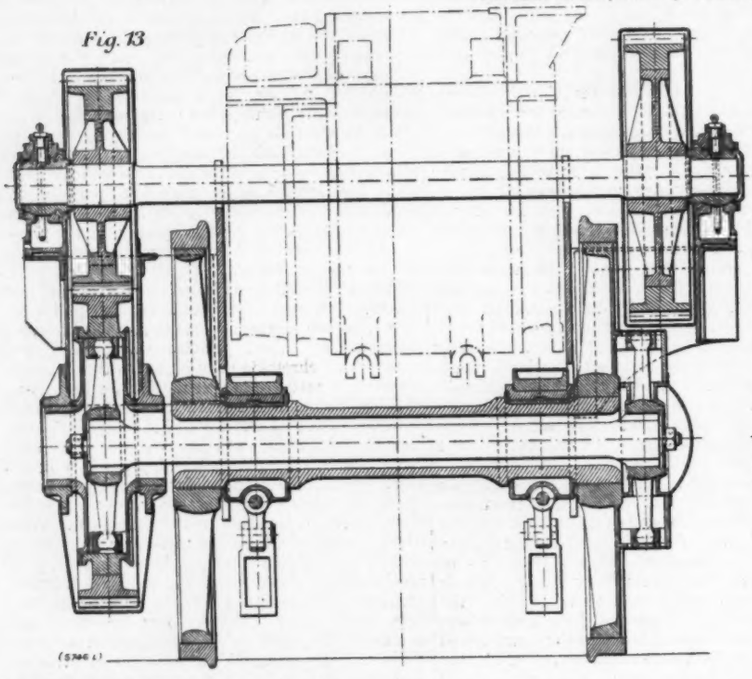
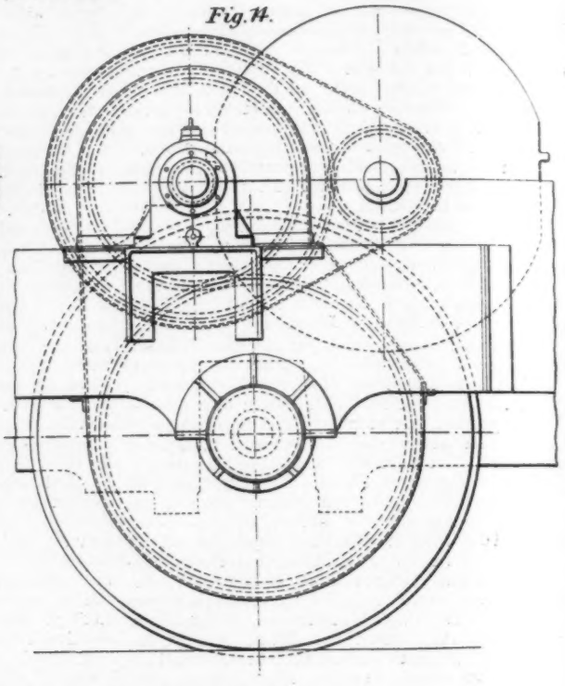


Fig. 14.



from the adoption of coupling rods, at least in the case of comparatively large powers. The reason for this is partly because the Americans believe in splitting up the output required over several small motors, which is practically the opposite of the opinion held here. In both cases the designers have perhaps gone to extremes, and it may be expected that in the end the golden mean will be found best. The tests at present in progress with the test locomotive mentioned represent a step towards the solution of the problem of the single drive. The simplest type of electric locomotive will doubtless be that which, as regards the mechanical construction, approaches to the simple form adopted in railway carriage building. The so-called tram suspension of the motor allows of such a construction being employed to the fullest extent, and it is of interest to see how far it is possible to build and drive locomotives with such a suspension.

The difficulties attendant upon the coupling-rod drive on heavy locomotives are well known. They are due principally to the periodical change in direction of the forces in the coupling rods and corresponding changes in the pressure on the bearings.

As shown in the diagram, Fig. 10, on page 564 *ante*, the power transmitted from the gear wheel through the coupling rod is zero at the end positions A and C, and reaches a positive and a negative maximum half-way, at the points B and D respectively, assuming constant torque at the crank-pin of the gear wheel. The forces in the rods and at the bearing vary approximately according to a sine curve, and it is necessary to design these parts for the maximum force F *max.*, instead of only for the average $F\,m = \frac{2}{\pi} F\,max.$, and, further for the most unfavourable conditions, that is, with F *max.* varying constantly from a maximum in one direction to a maximum in the reverse direction. The individual drive gets over these disadvantages and does not require that the distance between centres of the axles be kept constant or the wheel diameters equal. It therefore possesses advantages over the coupling-rod arrangement. The adoption of the individual drive with tram suspension is, however, limited by the power that can be transmitted per axle and the part of the motor weight carried directly by the latter independently of the springs.

SINGLE AXLE DRIVE, BROWN, BOVERI SYSTEM.

Fig. 15.

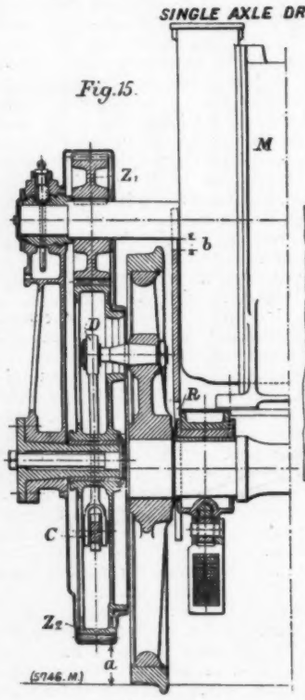
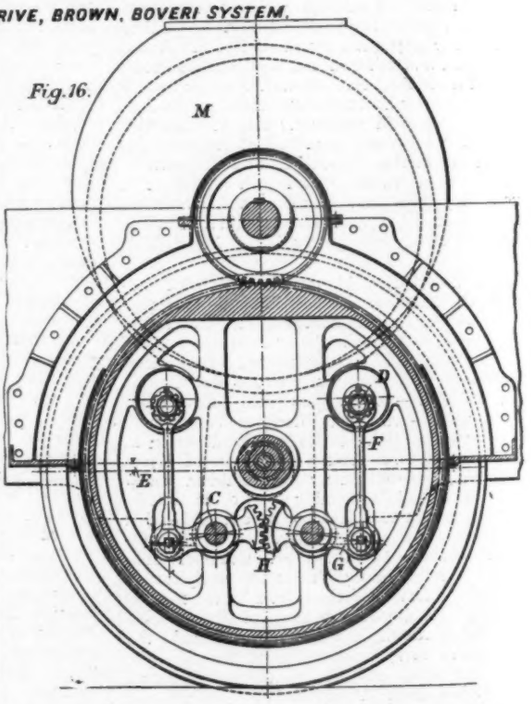


Fig. 16.



The amount of this weight is a function of the speed, that is, it must be kept smaller as higher speeds are adopted. In consideration of this it is seen that the tram suspension is specially suitable for goods locomotives, as here it is a case of low speeds, many driving axles, and high tractive effort with relatively low powers. According to the calculations of Brown, Boveri and Co., it should easily be possible to go up to 350 h.p. (continuous rating) per axle for single-phase locomotives, assuming that an average speed of 22 m.p.h. to 28 m.p.h. would not often be exceeded. Such a single-phase motor would weigh about 4 tons or 5 to 6 tons, including gearing.

The adoption of the single drive for express locomotives is a much more difficult matter. As a rule three driving axles are sufficient for express trains running under the conditions as found generally in Europe. In view, however, of the better performance expected from electric locomotives, as compared with steam, we may reckon that a modern express train driven electrically will

SINGLE-AXLE DRIVES FOR ELECTRIC LOCOMOTIVES.

Fig. 17.

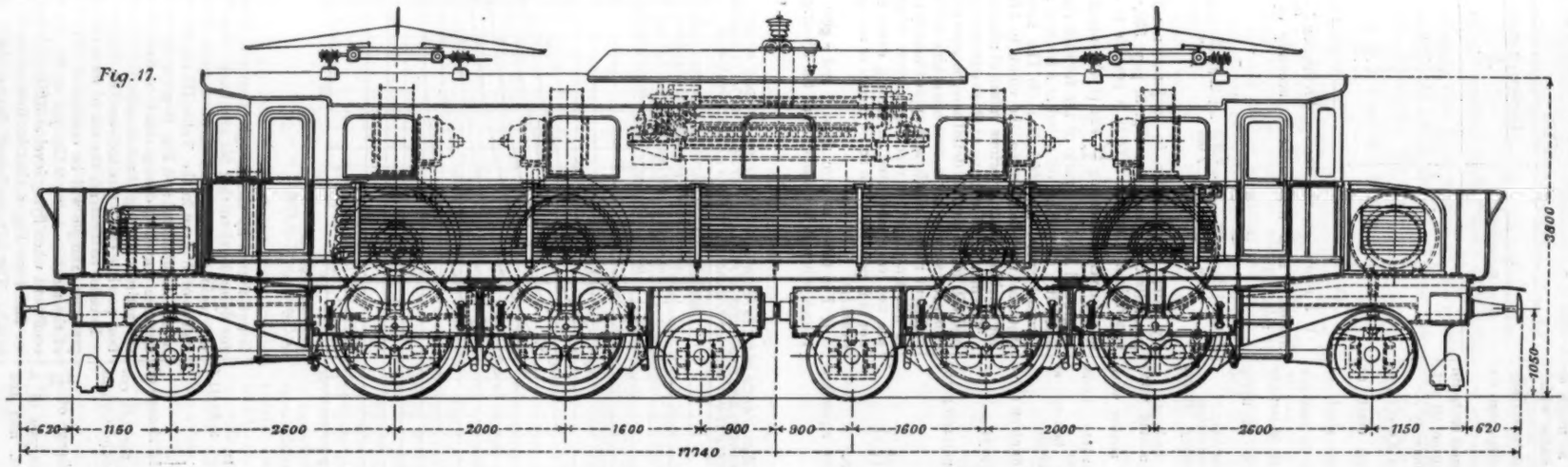


Fig. 18.

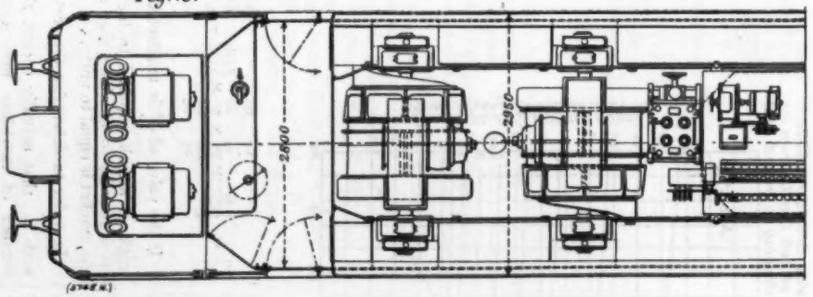


Fig. 19.

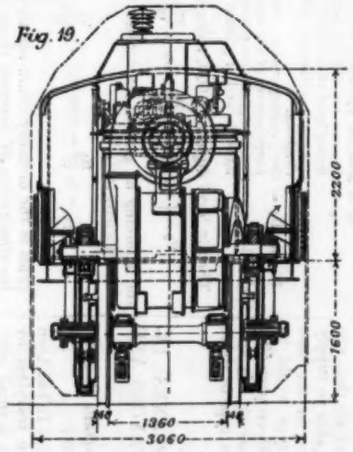
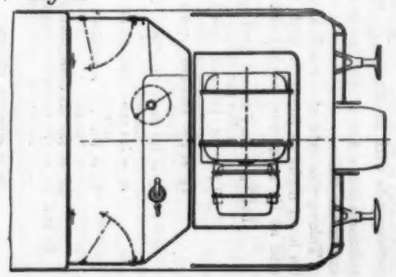


Fig. 20.



require four driving axles with a power per axle of 700 h.p. to 800 h.p. continuous rating. Motors of such a size cannot be fitted with tram suspension in the usual way, and even were this possible the high speed of over 60 m.p.h. would almost prohibit the use of such motors partly supported by the driving axle. The solution of the problem consists in introducing a flexible driving connection between the axle and motor, the latter being carried entirely by the locomotive frame. This arrangement is installed for testing purposes on the locomotive already mentioned, and should overcome the difficulty in adopting the individual drive for express locomotives.

The instigator of the tests on this subject is Mr. Tschanz, chief engineer of the Swiss Federal Railways, who designed one of the drives on the locomotive in question. The other driving gear on this engine is according to Brown, Boveri and Co.'s own design. In both cases the whole breadth of 4 ft. 1 in. between the side plates of the locomotive frame is available for the motor. This distance allows of a better proportion between length and diameter of motor than is the case with the rather limited space of 3 ft. 3 in. for a motor with tram suspension.

The motor is fitted in the frame with spring supports, and has a gear drive with the spur wheels carried by a frame at the outside of the driving wheels. A universal flexible connection connects the gearing to the latter. In the arrangement by Tschanz a cardan shaft is used with one end connected to the spur wheel, and the other with the driving wheel at the opposite side of the locomotive, the shaft being placed inside the hollow axle, as indicated in Figs. 13 and 14, on page 590. As the diameter of spur wheel for a given diameter of driving wheel is fixed by the maximum overall section allowable for the rolling-stock, we arrive at a gear ratio of 1 : 2·2 with single reduction. For motors of 500 h.p. to 700 h.p., however, it is found necessary to have a ratio between 1 : 3·5 and 1 : 2·5, so that double reduction gear must be resorted to. The Brown Boveri system is shown in Figs. 15 and 16, on page 590. The motor drives the spur wheel Z 1 of the single-reduction gear Z1–Z2, which is carried at the outside of the driving wheel by a fixed frame, the driving wheel being connected to the spur Z2 by means of a set of links free to move like a universal joint. This flexibility has a twofold purpose, viz.: of allowing for the variations in the relative positions of the spur and driving wheels due to the action of the springs, and of permitting the centre of the spur wheel Z2 to be placed higher than the centre of the driving axle. The latter condition allows of a larger spur

wheel and smaller pinion, that is to say, an increase in the ratio of reduction, which means a higher pinion speed and therefore smaller motor, other things being equal. The maximum diameter of the spur wheels with this design is fixed on the one hand by the minimum clearance *a* allowable from the gear case and, on the other hand, by the minimum safe distance *b*, between the motor shaft and wheel flange. The flexible coupling links connect the two driving pins *c* of the spur wheel with the coupling pins D of the main wheels through the intermediate element consisting of the links F and oscillating levers G. By having the spur wheel 2 in. eccentric it is possible to increase the gear ratio to 1 : 4. The drive described can be arranged on both sides of the locomotive, the motor bearings being placed well outside and therefore easily accessible. The space available is sufficient for bearings and gearing for much higher powers than those on which the design shown in Figs. 15 and 16 is based, and by efficient utilisation of the space it should be possible to raise the power to 1,000 h.p. per axle. The test locomotive has now been running for some months and, as the driving gears have given every satisfaction from the commencement and fulfilled all that was required of them, it is hoped to be able to supply locomotives with singly-driven axles in the case of the next group required. The type would be similar to that shown in Figs. 17 to 20, on page 591. A fuller description of the development of, and experience obtained with, the above type of drive may be made at a later opportunity.

AIR MILEAGE OF AEROPLANES INTENDED FOR LONG DISTANCES AND FOR TRANSPORT.

By J. DENNIS COALES, D.Sc., Captain R.A.F.

(*Continued from page 560.*)

The Preliminary Climb to 5,000 ft.—It has been previously stated that the distance travelled by the aeroplane in climbing to 5,000 ft. is small compared with the total range in a long-distance flight. This statement requires justification, and it is also necessary to ascertain whether a machine designed to fly level at its maximum aerodynamic efficiency, with its engines all out, will have a sufficient rate of climb at ground level to enable it to get off, and at what speed it will require to run before it will do so.

A little consideration will show that in the case of a machine designed to fly level at, say, 5,000 ft. with its maximum aerodynamic efficiency it is advantageous for climbing to increase its lift coefficient (by increase of angle of attack) above that which it has when flying level at 5,000 ft. The analysis of the trial of any ordinary aeroplane shows that the curve connecting its values of $\frac{L_c}{D_c}$ with L_c is very flat over the portion which corresponds with maximum $\frac{L_c}{D_c}$, and that the lift coefficient L_c can be varied up to as much as 20 per cent. on either side of that value which corresponds with maximum $\frac{L_c}{D_c}$ without materially reducing the value of the latter quantity from its maximum value.

Taking the case of a machine designed to begin its level flight at 5,000 ft. with its engine all out, and at its maximum aerodynamic efficiency :—

Let V_0 = its forward level speed at 5,000 ft. in miles per hour.
V_1 = its forward speed during climb at ground level per hour.
V_0' = its forward speed during climb at 5,000 ft.
v_1 = its rate of climb at g.l. in feet per minute.
v_0 = its rate of climb at 5,000 ft. in feet per minute.
L_c = the lift coefficient at 5,000 ft. flying level.
L_c' = the lift coefficient when climbing.
D_c and D_c' = the corresponding drag coefficients.
η_m = maximum airscrew efficiency (during level flight).
η_1 = airscrew efficiency while climbing.
n_0 = airscrew revolutions per minute when flying level at 5,000 ft.
n_1 = airscrew revolutions per minute when climbing.
H_0 and H_1 = the corresponding standard brake horse-powers of the engine.
$f(\rho_0)$ and $f(\rho_1)$ = the height-horse-power factors at 5,000 ft. and at ground level.

Then in level flight at 5,000, using equation (1)—

$$V_0 = \left(\eta_m \frac{L_c}{D_c}\right) \times \frac{H_0}{n_0} \times n_0 \times \frac{375}{W} \times f(\rho_0)$$

and climbing at ground level after increasing the lift coefficient to L_c'—

$$\frac{v_1}{33} = \eta_1 \frac{H_1}{W} \times 1000 f(\rho) - \frac{V_1}{0{\cdot}375}\left(\frac{L_c'}{D_c'}\right)$$

(This is the ordinary climb equation.)

By eliminating W between these two equations we obtain

$$\frac{v_1}{V_1} = \left[\frac{\eta_1}{\eta_m} \times \frac{\frac{V_0}{n_0}}{\frac{V_1}{n_1}} \times \frac{\frac{H_1}{n_1}}{\frac{H_0}{n_0}} \times \frac{f(\rho)_1}{f(\rho)_0} - \frac{\frac{D_c'}{L_c'^{\frac{3}{2}}}}{\frac{D_c}{L_c}}\right] \times \frac{D_c}{L_c} \times 88 \quad (11)^*$$

If the value of $\frac{L_c}{D_c}$ is unaffected by the change of angle of attack required to increase the lift coefficient to L_c' for climbing, then the second term in the bracket is equal to unity.

In order to determine the sort of change of $\frac{L_c}{D_c}$ with L_c, that actually occurs, the analyses of a number of machines were examined, and the following Table III gives the maximum variations found, expressed in fractions, see also Fig. 10.

TABLE III.

$\frac{L_c'}{L_c}$ at Maximum $\frac{L_c}{D_c}$	Fractional Reduction of $\frac{L_c}{D_c}$
0·7	0·09
0·8	0·038
0·9	0·01
1·0	0·0
1·1	0·01
1·2	0·03
1·3	0·06
1·4	0·10

If δ represents the fractional reduction $\frac{L_c}{D_c}$ when climbing, then with sufficient accuracy equation 11 becomes

$$\frac{v_1}{V_1} = \left[\frac{\eta_1}{\eta_m} \times \frac{\frac{V_0}{n_0}}{\frac{V_1}{n_1}} \times \frac{\frac{H_1}{n_1}}{\frac{H_0}{n_0}} \times \frac{f(\rho)_1}{f(\rho_0)} - 1 - \delta\right] \frac{D_c}{L_c} \times 88 \quad (12)$$

By using this relation in conjunction with the generalised engine curve Fig. 3, page 559, and a generalised airscrew curve it is possible to calculate curves connecting $\frac{L_c'}{L_c}$ and (1) the rate of climb at ground level as a ratio of the forward speed at 5,000 ft.; (2) getting off speed at a fraction of the forward speed at 5,000 ft.; (3) The horizontal distance travelled during the climb to 5,000 ft. for machines having various values of maximum.

The method of arriving at these curves is lengthy and will not be given in detail here, because although it is necessary to know that a machine will have a sufficient rate of climb, and approximately how far it will travel before reaching a given height, we are not very interested in finding exact figures, nor is it possible to do so by means of any general relations.

If δ is taken as zero Figs. 7 and 8 give these values, when it is assumed that the lift-drag ratio is not altered by the change of attitude from that for flying level to that for climbing. Fig. 9 gives the ratio of climb and forward speed when the values of δ given in the Table III are allowed for in the calculations, and Fig. 10 gives the minimum distance travelled during climb to 5,000 ft. when the attitude during climb is adjusted to give the best possible climb rate indicated on Fig. 9.

In order to illustrate the use of these curves the previous example will be continued. The loading of the machine being 9 lbs. per sq. ft. and its lift coefficient when flying level at 5,000 ft. being 0·35, we find from Fig. 6 that its forward speed is 76 m.p.h. The lift coefficient during climb can be safely increased to 0·4 so that $\frac{L_c'}{L_c} = 1{\cdot}15$. Suppose that the maximum propeller efficiency is

Fig. 7. RATIO OF RATE OF CLIMB AT G.L. TO LEVEL SPEED AT 5000 FT With Maximum L_c/D_c for various changes of Lift Coef. L_c from its value in level flight at 5000 Ft. to that for climbing at ground level.

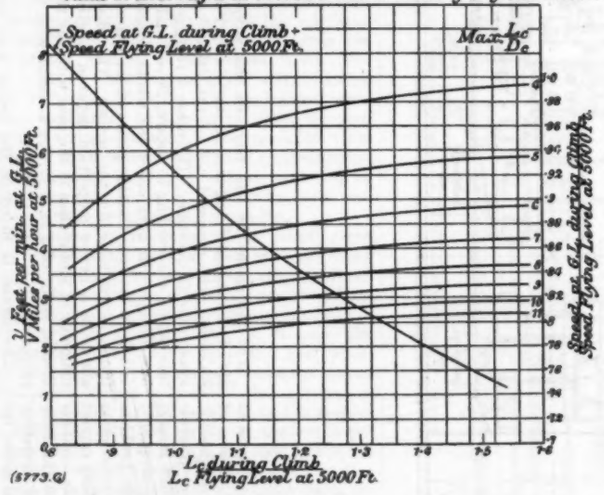
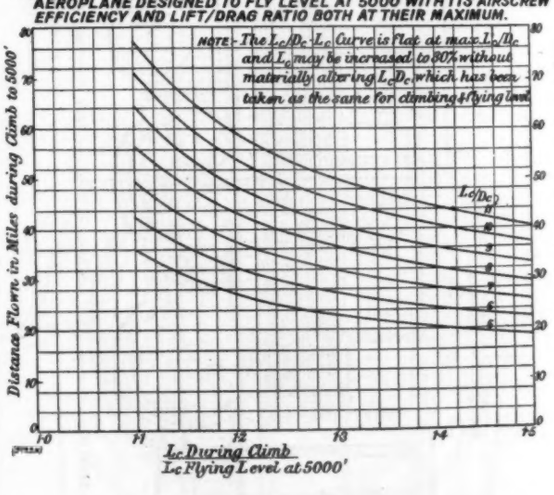

Speed at G.L. during Climb ÷ Speed Flying Level at 5000 Ft.
Max. Lc/Dc
v Feet per min. at G.L. ÷ V Miles per hour at 5000 Ft.
Speed at G.L. during Climb ÷ Speed Flying Level at 5000 Ft.
Lc during Climb / Lc Flying Level at 5000 Ft.
(5773.G)

Fig. 8. DISTANCE IN MILES FLOWN DURING CLIMB TO 5000' BY AN AEROPLANE DESIGNED TO FLY LEVEL AT 5000' WITH ITS AIRSCREW EFFICIENCY AND LIFT/DRAG RATIO BOTH AT THEIR MAXIMUM.


NOTE - The Lc/Dc - Lc Curve is flat at max. Lc/Dc and Lc may be increased to 80% without materially altering Lc/Dc which has been taken as the same for climbing & flying level.
Distance Flown in Miles during Climb to 5000'
Lc/Dc
Lc During Climb / Lc Flying Level at 5000'

* Although level flight at 5,000 ft. has been mentioned to fix ideas, equation 11 is true for any height, provided that the appropriate value of $f(\rho_0)$ is used.

0·75, then since $\eta \frac{L_c}{D_c} = 6$ we find $\frac{L_c}{D_c} = 8$.

Assuming first that $\frac{L_c}{D_c}$ is unaltered by change of attitude for climbing, we find from Figs. 7 and 8

$\frac{v_1}{V_0} = 3{\cdot}3$ and $v_1 = 3{\cdot}3 \times 76 = 250$ ft. per minute.

also distance travelled during climb = 49 miles. Now supposing that $\frac{L_c}{D_c}$ is reduced by the change of attitude to the extent already indicated; then using Figs. 9 and 10. We find:—

$\frac{v_1}{V_0} = 3{\cdot}14$ and $v_1 = 239$ ft. per minute.

and the minimum distance travelled during climb 56 miles. In both cases the getting off speed is given by $\frac{V_1}{V_0} = 0{\cdot}86$ or $V_1 = 65$ m.p.h., corresponding with the attitude adopted during climb. By still further increasing the angle of attack the getting off speed may be reduced, but the climb rate will be smaller until the smaller angle is resumed.

The above values of the rate of climb and the distance travelled do not differ from each other widely in the two cases, because only a small change was allowed in L_0 for climbing. If a bigger change is assumed then the differences would be larger, and the rates of climb and distance travelled, when allowance is made for reduction in $\frac{L_c}{D_c}$ must be calculated from the ratios given in Fig. 9 and the relation

$$d_{miles} = 95{\cdot}8 \times \frac{\left(\frac{V_1}{V_0} + \frac{V_0^3}{V_0}\right)}{\left(\frac{v_1}{V_0} - \frac{v_0}{V_0}\right)} \times \log_{10} \frac{\frac{v_1}{V_0}}{\frac{v_0}{V_0}} \quad . \quad (13)$$

It is not generally worth while to do more than calculate the rates of climb and distance travelled by means of Figs. 9 and 10 for the results so obtained will generally give a sufficiently close idea of the values to be expected. It must be remembered that they indicate the climb performance of a machine that is designed to have its engine running all out in level flight at 5,000 ft. with the machine at its most efficient attitude. Under these conditions the rate of climb will always be small because the only sources of power for climbing are the small saving of power by the reduction of forward speed accompanying the increase of lift coefficient, and the gain of engine power at ground level because the air density there is greater than that at 5,000 ft. In the case of a high-speed machine which flies level at an aerodynamic efficiency much below its maximum value, the change to climbing attitude greatly increases its aerodynamic efficiency and reduces its forward speed so that there becomes available a comparatively large amount of power for climbing, and a high rate of climb is obtained.

This is what ordinarily occurs in a fast single-seater or two-seater machine.

But such a machine will have a comparatively low air mileage because at top speed when its rate or petrol consumption per brake horse power hour is low, its aerodynamic efficiency $\eta \frac{L_c}{D_c}$ is also low.

Equation 3 shows that for a high value of m (the pound miles per pound of petrol), p must have its minimum value at the same time as $\eta \frac{L_c}{D_c}$ has its maximum value. This condition can only be fulfilled in a machine designed to fly with its engine all out at a speed corresponding to the attitude of maximum aerodynamic efficiency, which is not the top speed of the machine, and can never be very high if moderate landing speeds are to be retained.

The qualities of an aeroplane, which are required to meet the demands of aerial warfare are very different from those which are necessary for the enterprises of peace, and they impose restrictions on design which render war aeroplanes unsuited for commercial purposes.

The high speed and large rate of climb which are necessities in the case of machines for aerial fighting, bring with them poor aerodynamic efficiency, and small weight lifting capacity. Even in the case of bombing aeroplanes a high speed is of importance, and this involves the provision of a large amount of horse power in proportion to weight, and the consequent expenditure of weight carrying capacity in carrying engines rather than dead weight. The speed being high, more especially if it is a day bomber, in the proportion to the landing speed, which must be low, renders it necessary to fly the machine at an attitude which has an aerodynamic efficiency considerably below that which the machine can attain. Again in the case of fighting machines, which must be able to bear the stresses on the structure caused by the aerobatics of an aerial combat, it is necessary to provide for a higher factor of safety in the structure, than is necessary in a machine used for commercial purposes in which "stunting" is not required. Part of the weight-lifting capacity of a fighting aeroplane is therefore absorbed by the weight added to its structural members, and a good deal of weight carrying capacity is sacrificed to obtain high factors of safety.

The limitations imposed upon air mileage by weight economy of design and the factor of safety.—In the preceding portion of the paper it has been shown how the ratio of the weight of petrol to the total weight of an aeroplane limits its maximum possible air mileage. In order to come to more definite conclusions as to the possibilities that are presented by the design of modern aeroplanes in carrying capacity and range, it is necessary to examine in a general way the limitations that weight economy in the design of the power plant and structure imposes upon the weight of petrol and dead load that can be carried without unduly reducing the factor of safety of an aeroplane.

The factor of safety referred to will be that of the wings structure when the machine is flying at its attitude of maximum aerodynamic efficiency.

Let s = structure weight per 1 lb. of total weight of aeroplane.

ϵ = the weight engine propeller, cowling, bearers, radiator, water and all piping, pumps and cocks per standard horse-power. The only power unit items excluded from this figure are the tanks for petrol and oil, the weight of which varies with the weight of petrol.

$(c + i)$ = the weight of crew, instruments, &c., per pound of total weight of machine.

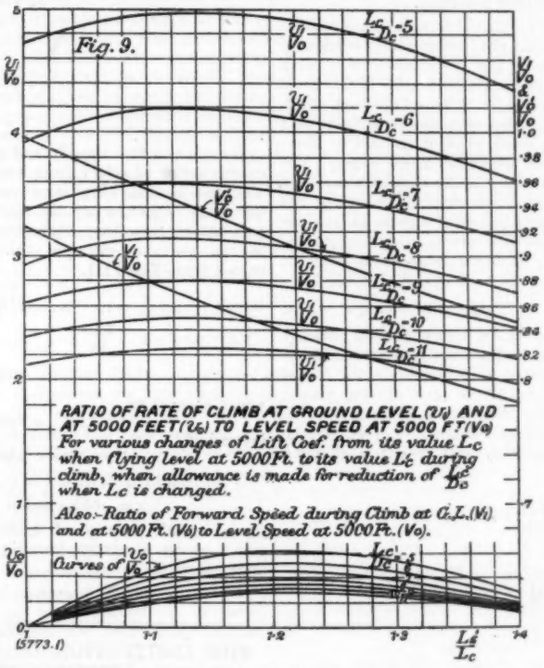
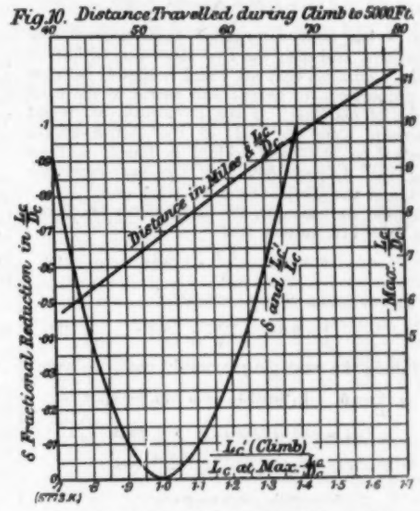


Fig. 9.
RATIO OF RATE OF CLIMB AT GROUND LEVEL (V1/V0) AND AT 5000 FEET (v1/V0) TO LEVEL SPEED AT 5000 FT (V0)
For various changes of Lift Coef. from its value Lc when flying level at 5000 Ft. to its value Lc' during climb, when allowance is made for reduction of Lc/Dc when Lc is changed.
Also:-Ratio of Forward Speed during Climb at G.L. (V1) and at 5000 Ft. (V1) to Level Speed at 5000 Ft. (V0).
Curves of V1/V0
(5773.I)



H = the standard horse-power of the engines.
P = the total weight of petrol.
o = the weight of oil per pound of petrol.
o_t = the weight of oil tanks per pound of oil.
p_t = the weight of petrol tanks per pound of petrol.
f = the weight of oil, oil tanks and petrol per pound of petrol.
l = the weight of dead load (i.e., freight) carried per pound of total weight of aeroplane.
r = pounds of petrol per pound of total weight of machine.
a = wing weight in pounds per pound of total weight.
O = the total weight of oil.

Then $\epsilon \times H$ = weight of engine, propeller, cowling, &c., and $\epsilon \times \frac{H}{W}$ = weight of engine, propeller, cowling, &c., per pound of total weight of aeroplane. If λ represents the weight per standard horse-power of the aeroplane, then ϵ/λ = weight of engine, propeller, cowling, &c., per pound of total weight of aeroplane.

Also

$$f = o(1 + o_t) + p_t$$

and

$$l = 1 - \frac{\epsilon}{\lambda} - (1 + f)r - (c + i + s) \quad . \quad (14)$$

The values of a, ϵ $(c + i)$, f and s for three modern twin engines aeroplanes, and a flying-boat (No. 4), which have factors of safety of the value 4, when loaded to the total weights stated, are given in Table IV. The values given were obtained by actually weighing in detail all the parts of the aeroplanes to which they refer, and give an indication of the tendency of modern design in the matter of economy in weight.

Equation (14) becomes a general relation between the proportions of freight and petrol to the total initial weight of the aeroplane when the quantities f, ϵ, c, i, s, and λ are known. The first five quantities depend upon the economy

TABLE IV.—*Factor of Safety of Wing Truss = 4.*

Aeroplane Weight in pounds.	Wing Weight / Total Weight.	Structure Weight / Total Weight.	Weight of Engine and Accessories per H.P.	Weight of Tanks and Oil per pound of Petrol.	Weight of Crew Instruments, &c. Total Weight.
	a	s	e	f	$c+i$
11,755	0·184	0·40	3·95	0·257	0·049
10,300	0·179	0·31	4·58	0·219	0·057
8,570	0·174	0·33	3·41	0·290	0·065
12,970	0·186	0·38	3·63	0·216	0·059
(Mean) 10,900	0·181	0·355	3·90	0·245	0·056
Minimum ..	0·174	0·310	3·41	0·216	0·049

in the design of the aeroplane, engine and tanks, and tend toward limiting values, of which some indication is given by the figures in Table IV. The value of λ depends upon the aerodynamic efficiency of the aeroplane in flight, and upon the speed at which it is flown. Or since speed is a function of wing loading, lift coefficient and density, λ depends upon these three quantities and upon the aerodynamic efficiency. It may be shown from first principles that:

$$\lambda = \eta \frac{L_c}{D_c} \times f(\rho) \times \sqrt{\frac{L_c \rho}{w}} \times 26.7 \quad . \quad (15)$$

When λ has been determined from general considerations, and also the five other quantities, we obtain a relation between l and r, that is between the proportions of freight and petrol to the total weight of machine. If the proportion of freight is known, then the ratio of the initial weight of petrol to the total weight is found, and by using Fig. 6, page 560 *ante*, the maximum air mileage of the aeroplane can be calculated.

Suppose, for example, the mean values are taken from Table III, we then find:

$$l = 0.589 - \frac{3.9}{\lambda} - 1.245\,r \quad . \quad . \quad (16)$$

or if the minimum values are taken:

$$l = 0.641 - \frac{3.41}{\lambda} - 1.216\,r \quad . \quad . \quad (17)$$

Continuing the example previously used, we have:

$$\eta \frac{L_c}{D_c} = 6 \qquad L_c = 0.35 \qquad w = 9 \text{ lb. per sq. ft.}$$

$$f(\rho) = 0.85 \text{ at } 5{,}000 \text{ ft.} \qquad \rho = 0.874$$

$$\lambda = 6 \times 0.85 \times \sqrt{\frac{0.35 \times 0.874}{9}} \times 26.7$$

$$\lambda = 25 \text{ lb. per horse-power.}$$

Equations (16) and (17) then become

$$l = 0.4433 - 1.245\,r \quad . \quad . \quad . \quad (18)$$

$$l = 0.505 - 1.216\,r \quad . \quad . \quad . \quad (19)$$

By using equations 18 and 19, we can now calculate the ratio of petrol to initial weight of aeroplane which is possible without reducing the factor of safety below 4, in the particular case where the value of λ is 25 lb. per horse-power, and for any given load ratio. Having so found the value of r, the air mileage over which the load can be transported is determined by using the curves of Fig. 6.

In the example taken the initial total weight of aeroplane was 20,000 lb. $\eta \frac{L_c}{D_c} = 6$. What is the air mileage over which a load of 4,000 lb. can be transported? here

$$l = \frac{4{,}000}{20{,}000} = 0.2$$

Assuming that the aeroplane is such as to have the mean values of Table III, we find

$$0.2 = 0.433 - 1.245\,r$$

$$r = 0.193$$

and from Fig. 6 the air mileage, assuming the flight to begin at 5,000 ft., is 900 miles.

Or supposing that the design is such that the minimum values of Table III are attained:

$$0.2 = 0.505 - 1.216\,r$$

$$r = 0.25$$

and the air mileage is 1,250 miles.

If the aeroplane were to carry no freight, as, for instance, in a cross Atlantic flight, we then find that r lies between 0·348 and 0·415, giving air mileages of 1,800 and 2,200 miles respectively. Since the flight would actually begin with a climb from ground level, all these air mileages must be somewhat reduced, because the forward speed during climb is less that that in level flight at 5,000 ft. In this case the lift coefficient was about 0·4 during climb, which with a loading of 9 lb. per square foot makes the forward speed during climb 65 m.p.h. at g 1, and 71 at 5,000 ft., giving a mean value of 68 m.p.h. The air mileage during climb was found to be about 56 miles, and the time occupied is, therefore, $\frac{56}{68} = 0.825$ hours, during which time in level flight the machine would have flown $0.825 \times 76 = 63$ miles. Thus the air mileage reckoned as if the machine began its flight at 5,000 ft. with full tanks, is over-estimated by about $63 - 56 = 7$ miles, a negligible amount for all practical purposes, which is more than compensated for by the distance travelled during the final glide to earth with the engines off.

It will be clear from these figures that if the factor of safety of a machine designed for cross-Atlantic flight is to be as high as 4, its design will have to be extremely good with respect to:—

(1) Aerodynamic efficiency.
(2) Economy in structure weight.
(3) Economy in weight generally.

The speed in level flight will have to be comparatively low in order that the aerodynamic efficiency, and the pounds carried per horse-power may both be as high as possible. Further, the flight must be made during a calm or with a following wind. The shortest distance between Great Britain and America is from the south-west of Ireland to Newfoundland, a distance of about 2,000 miles. The above figure of 2,200 miles in the case of a machine designed on the best of modern lines as regards the weight of its parts leaves a very small margin of air miles to allow for errors in piloting, unexpected winds, &c., during a cross-Atlantic flight. If the aeroplane were so well designed as to have a maximum $\eta \frac{L_c}{D_c}$ of 7, the air mileage would be increased to about 2,700 miles if flown steadily at its attitude of maximum aerodynamic efficiency.

The Effect of Allowing a Reduction in the Initial Factor of Safety.—Let a be the ratio of wing weight to total weight, when the factor of safety is k_1 and let W_1 be the total weight. Let k_2 be the factor of safety when the total weight is changed to W_2.

Then

$$\frac{k_2}{k_1} = \frac{W_1 - aW_1}{W_2 - aW_1} = \frac{1 - a}{\frac{W_2}{W_1} - a} \quad . \quad . \quad (20)$$

Let ΔK be the change in factor of safety when the weight is changed by an amount ΔW.

Then

$$\frac{k_1 + \Delta k}{k_1} = \frac{1 - a}{\frac{W + \Delta W}{W} - a}$$

which reduces to

$$\frac{\Delta W}{W} = -\frac{1 - a}{1 + \frac{\Delta k}{k}} \times \frac{\Delta k}{k} \quad . \quad . \quad (21)$$

The increase in weight will be utilised to increase the weight of freight and petrol, oil and tanks. Considering equation 14, and re-writing in the form:

$$l + (1 + f)r = 1 - \frac{e}{\lambda} - (c + i + s)$$

it will be seen that this becomes

$$l + (1 + f)r = 1 - \frac{e}{\lambda'} - (c + i + s)\frac{W_1}{W_2}$$

or

$$l + (1 + f)r = 1 - \frac{e}{\lambda'} - (c + i + s)\frac{1}{1 + \frac{\Delta W}{W}}$$

substituting for $\frac{\Delta W}{W}$ we get

$$l + (1 + f)r = 1 - \frac{e}{\lambda'} - \frac{(c + i + s)\left(1 + \frac{\Delta k}{k}\right)}{1 + a\frac{\Delta k}{k}}$$

where λ' is the new value of the pounds per horse-power.

The effect of allowing a change in factor of safety on the pounds per horse-power depends upon the conditions under which the flight is to be made. In our case we have supposed that the flight is made with the attitude of maximum aerodynamic efficiency. We must therefore provide increased engine horse-power of such an amount that the value of $\eta \frac{L_c}{D_c}$ is unaltered.

By equation (15)

$$\lambda = \eta \frac{L_c}{D_c} \sqrt{L_c} \times f(\rho) \sqrt{\frac{\rho}{w}} \times 26.7$$

That is, at any given height for a constant $\eta \frac{L_c}{D_c}$ we must have

$$\lambda \sqrt{w} = \text{constant}$$

or

$$\frac{\lambda'}{\lambda} = \sqrt{\frac{W_1}{W_2}}$$

$$\lambda' = \lambda \sqrt{\frac{1}{1 + \frac{\Delta W}{W}}}$$

which is the same as

$$\lambda' = \lambda \sqrt{\frac{1 + a\frac{\Delta k}{k}}{1 + \frac{\Delta k}{k}}}$$

We thus get for the new relation for l and r

$$l + (1 + f)r = 1 - \frac{e}{\lambda}\sqrt{\frac{1 + a\frac{\Delta k}{k}}{1 + \frac{\Delta k}{k}}} - \frac{(c + i + s)\left(1 + \frac{\Delta k}{k}\right)}{1 + a\frac{\Delta k}{k}} \quad . \quad (22)$$

We can now find the effect of allowing a reduction of the factor of safety from 4 to 3 in the case of a machine having wing structure weight 0·174 of the total weight, when the factor of safety was 4, and having the other characteristics the same as in the previous example taking the minimum values from Table III.

Here $\Delta k = -1$, $a = 0.174$, $k = 4$

$$l + 1.216\,r = 1 - \frac{3.41}{25} \times \sqrt{\frac{1 - 0.174 \times \frac{1}{4}}{1 - \frac{1}{4}}} - 0.359 \times \frac{1 - \frac{1}{4}}{1 - 0.174 \times \frac{1}{4}}$$

which reduces to

$$l + 1.216\,r = 0.5642$$

instead of

$$l + 1.216\,r = 0.505 \text{ (equation (19))}$$

If no freight is carried $l = o$ and

$$r = .463 \text{ instead of } .415,$$

giving an air mileage of 2,550, as against 2,200, which shows a smaller gain in air mileage than might have been expected.

(To be continued.)

THE INSTITUTION OF MECHANICAL ENGINEERS.

AN ordinary general meeting of the above Institution was held on Friday evening last, the 2nd inst., in the hall of the Institution of Civil Engineers. The president, Dr. Edward Hopkinson, M.P., was in the chair. The Minutes of the previous meeting having been read and confirmed, and a list of seven transferences read by the secretary, the meeting immediately passed to the main business of the evening.

THE MECHANICAL PROPERTIES OF STEEL.

This was concerned with the reading and discussion of a paper by Dr. W. H. Hatfield, entitled "The Mechanical Properties of Steel, with Some Consideration of the Question of Brittleness." The paper, which we reprint on page 617, was summarised in a short lecture by Dr. Hatfield.

The president, in proposing a vote of thanks to the author for his very valuable paper, said that he was quite incompetent to take part in the discussion on its technicalities, but he knew enough of the subject to be able to appreciate its great value, which was greatly extended by the addition of the bibliography.

Mr. J. Rossiter Hoyle, in opening the discussion, said that he could not at the moment discuss from a scientific point of view the great number of interesting details with which the author had dealt. He had had the pleasure and great satisfaction of seeing a good deal of the work in preparation and

of considering the absolutely novel points of view which the author had taken in dealing with the subject. He therefore could heartily support the vote of thanks, but he must leave it to more scientific minds to criticise the various points that had been raised. He naturally took the author's ideas and views almost entirely as his own, as they had talked them over together, and he had been convinced almost at first hearing. He hoped, therefore, he would be excused if he did not enter into a detailed discussion of any of the points that had been raised, particularly as he knew there were many members present eager to contradict many of the author's statements and, generally speaking, to pull the paper to pieces. He hoped they would do so, because the author would then have the opportunity of trying to piece it together again.

Mr. R. G. C. Batson said there were one or two points in the paper to which he specially desired to refer, the first being the statement in reference to the speed of application of the blow in impact tests. The author said that the view that the speed of application of the blow had an effect on the notched-bar test was a mistaken one. He wished to ask the author if he would state the information on which he based that view, because just lately he had seen some unpublished work in which with certain steels the speed of application of the blow on the notched bar had a very decided effect on the result. Some time ago some work was carried out at the National Physical Laboratory on various speeds of impact with a 30 mm. by 30 mm. by 160 mm. Charpy test-piece. The material used was a mild steel, the two speeds of impact being 28 ft. per second and 15½ ft. per second. The steel had been carefully normalised at 900 deg., and the results were of great interest. The energy absorbed in kilogramme-metres was as follows:—

28 ft.-sec.	15½ ft.-sec.
13·6	68·2
75·0	78·3
15·4	68·0
14·7	
76·3	

It would be seen that at 28 ft. per second the test pieces split themselves up into two distinct groups, three with a very low value and two with a high value, which was the same as that of the lower speed results. The low value was even lower than was obtained with the same type of test-piece with a high carbon steel. The figures seemed to show that, at the higher velocity and with the particular type of test-piece and notch used, there was a critical point with the steel in which a high value or a low value might be obtained. They suggested that the notched-bar test might not be a reliable indication of brittleness in a material, because, supposing the low value was obtained on the test, it might immediately be assumed the material was brittle, whereas if some more testing was done and higher values were obtained it would be said that the material was not brittle. He thought the whole question was bound up with the speed of striking. the shape of the notch, and the microstructure of the test-piece. In the particular case concerned, the microstructure was examined and also the chemical analysis taken, and no difference between the samples was found.

The other point to which he desired to refer was the author's description of the Stanton test. The method of testing was that suggested and used by Dr. Stanton, but the machine the author described was not the machine which was designed by Dr. Stanton and used for his tests. Dr. Stanton's machine was described in a paper which was read before the Institution in 1908. The machine described by the author was a machine constructed by the Cambridge Scientific Instrument Company to carry out Dr. Stanton's method of testing. The main difference between the two machines was that the Cambridge Scientific Instrument Company's machine must have a very firm foundation in order to obtain comparative results, whereas the machine originally designed by Dr. Stanton was independent of the form of foundation. He believed there was also another machine of the same type made by the Edon Foster Machine Company, which very closely resembled Dr. Stanton's machine.

Professor Henry M. Howe, of New York, said he was greatly indebted to the author for his extremely interesting paper, for the many important facts which he had brought together, and for his courage in stating his views. He thought it was Tyndall who said that every carefully-thought-out hypothesis should be welcomed as valuable if for no other reason than that it led to the truth by provoking opposition. There were a good many points raised by the author which provoked opposition. In the first place, he thought some of the members would question the propriety of saying that any one test was fundamental. He would like to ask what the author meant by "fundamental." He assumed he meant that it was more trustworthily indicative of the fitness of the material for its intended use. The important point raised in the paper was, he understood, the philosophy of testing. As he took it, the purpose of testing was to ascertain the fitness of the material for the intended service, service which might vary from rivets to piano wire or razors. He thought engineers would be very reluctant to say that any one test must necessarily be the most trustworthily indicative for all ranges and all services of steel; indeed, was it not necessary in view of the present state of pretty dense ignorance as to the relation between the results of tests and service utility, to apply several different tests? None of the tests simulated the conditions of service with any degree of closeness; and because of their remoteness from the conditions of service they threw only an indirect light on the fitness of the material for service. Owing to that indirectness, the tests themselves should be multiplied in order that a defect which one test failed to detect might be detected by others.

If a firm wished to hire a man for a specific work they examined him and looked at him. If the work required great precision and great care, and there were spots on the man's waistcoat he was rejected summarily. On the other hand, if precision was not of any importance that phenomenon was disregarded altogether. In hiring a man for any particular service there were a larger number of evidences of his fitness for that service, and the points to which attention should be directed would vary with the nature of the service. In testing steel to determine its fitness for service, it must be made a fundamental law that several tests must be employed, so that defects not found out by one test could be detected by another if they were present, but the most indicative test would be the one which reproduced most closely the conditions of service. If the service was wholly free from impact, relatively little attention would be paid to the impact tests; if, on the other hand, the service implied impact, then very great weight would be attached to the impact tests. If the service was in the nature of a notched-bar, if, for instance, the material was to be used in a threaded condition, then naturally one would look very attentively at impact tests made on notched bars. If the material was to be used in a perfectly smooth state without any notches of any kind, it was reasonable to ask why it was legitimate to test the material in a notched state, when as a matter of fact it was going to be used in a wholly different state; and if impact tests were to be made under those conditions should not they be made on unnotched bars? He did not mean to say that that was necessarily the case, but in considering the subject of testing philosophy those were questions which they naturally asked themselves and which should be fully investigated.

He desired to demur a little at the way in which the author used the expression "true brittleness." The author found that no adjective existed to describe a property which he wished to describe; he found material which was brittle under certain conditions and not brittle under other conditions. In his opinion if no adjective existed which described that state there was nothing for engineers to do but to invent a new adjective to fit the case. The members were apt to smile and perhaps to be displeased when anybody proposed a new word, but it must be remembered that every word in the dictionary was a new word when it was used for the first time, and that the whole wealth of the Anglo-Saxon language, and every other language, was due to the ingenuity of an enormous number of people who had proposed new words when the need for them arose. He thought the author had developed the need for a new word in the present instance, but he thought such new words should be proposed with very great care. He therefore questioned whether it was quite advisable to speak of one form of brittleness as "true brittleness" and other forms of brittleness as "false brittleness." Brittleness of any form was brittleness, and in order to distinguish brittleness of one kind from that of another kind it was necessary to modify the adjective or invent a new one. The only further thing he desired to say was with regard to the question of the rapidity of cooling from about 600 deg. He found that as far back as 1883 that was a phenomenon well known at least to many blacksmiths.

Sir Henry Fowler, K.B.E., thought that one of the most practical points the author had raised was in turning the attention of the members to the fact that they did not bring forward particulars of the many failures that occurred. There were undoubtedly a large number of cases such as those to which the author had referred in which investigation should take place. Personally he thought it would be of the very greatest benefit if once a year a frank discussion took place at the Institution on the failures that had occurred during the year to themselves and to their fellow members. If that had been the case he would not have been in the unfortunate position of having to refer to two failures which he met with which unfortunately he was not able to explain. One was the case of a reel bar of about 2½ in. diameter, which happened in the early days of reel bars. The side of the low-sided wagon in which the bars were transported was let down, and the stuff fell on the ground, and one of the bars broke. No doubt the failure was to be explained by the author's sentence: "It is now firmly established that the stresses become increasingly great locally to a notch according to its sharpness." He desired in that connection to call attention to the remarkable paper which was read before the Institution about two years ago by Messrs. Taylor and Griffith on the method of determining torsional stresses by means of soap films,* to which that particular case could be applied. In the work there described one could at once see the very great increase of the stress with the sharpness of the notch.

He was glad that Professor Howe had raised the question of true brittleness, because later in his remarks he intended to refer to the question of whether a steel was truly brittle or not. The author would probably tell him that it was not, but as a matter of fact the stuff broke. The statement was made in the paper: "It is also evident that certain steels under like conditions of treatment develop intrinsic differences more readily than others, but it is claimed by the author that true brittleness is readily discovered in the mechanical testing laboratory, and shows itself in the tensile and other values obtained." He wished to refer to that more particularly with regard to the question of tyres, but before proceeding he would say in regard to the microstructure of the railway locomotive tyre shown in the paper, that he thought it had a great deal too much ferrite in it. He would look with suspicion upon such a tyre offered to him for locomotive purposes, although it gave, it was true, a perfect tensile test. The author also suggested that an effort should be made to calculate the stresses which came on locomotive tyres. That was a thing one would like to do, but it was a matter of the greatest difficulty. That the locomotive tyre under ordinary conditions was a most successful proposition was borne out, he thought, by the fact that in the ten years before the war he remembered only two breakages on 3,000 locomotives in which the break could have been due to brittleness. In one case the manufacturers who supplied the tyres said that the railway company shrunk the tyre on too hard. In the second case the tyre was broken as it was lifted out of the wagon, before it went into the store. He deplored that a sample of that tyre was not kept in order that it might be handed over to the author for investigation. The tyre gave a good mechanical test as far as his memory carried him, but as a practical article it was a failure.

He had stated that before the war very few

* See ENGINEERING, vol. civ., page 652 *et seq.*

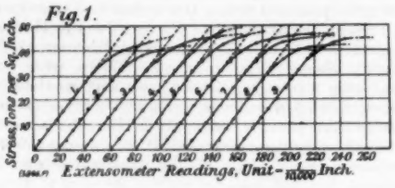
breaks had occurred, but tyres had broken during the war, although not very many of them. Of course, there were reasons for that. There were no doubt cases in which broken tyres had occurred which, according to the tensile tests, had given most excellent results. Nevertheless they had broken. They had some form of brittleness. They had been put on in exactly the same way as all tyres were put on, but they failed. The tensile test employed was a static test, but it did not, as Professor Howe said, deal with the conditions under which the material had to run. Unfortunately his impact-testing machine was an old one and a small one, and he was thus unable to compare the few figures he possessed of tyres with those which the author had given. Certain portions of a tyre were probably at times stressed beyond their elastic limit, and that was still more the case with regard to locomotive cranks. Locomotive cranks were not scrapped because they wore but because they developed flaws which grew, and he took it that those flaws were due to the fact that the material was strained beyond its elastic limit. In addition to the mechanical tests on a crank, he was very insistent that the manufacturer should produce a good microstructure. That was put in the specification, and the steel-maker inquired what was meant by a "good microstructure." The answer was, "Not a bad microstructure." There were certain microstructures that were acknowledged to be bad, but it was not so easy what was a good one. There was, however, a good microstructure for crank steel which he hoped to be able to show before long; he did not want to be pressed to say what it was at the present time.

There was one other point with regard to locomotive cranks that he desired to mention, namely, that there was some relation between the life obtained from a crank and the elongation of the test bar taken from the worst position. There, again, in the elongation test they were dealing with something which took place beyond the elastic limit, and that was really very remarkable. Locomotive crank axles lasted for a very large number of years, with the result that a practical test could not be obtained except over a very long period. His friend and assistant, Mr. Tredgold, had been paying attention to the matter, so far as elongation went, for the past twelve or fifteen years. Unfortunately their investigations in regard to the impact test and in regard to a modified Arnold test, which again depended on work done beyond the elastic limit, were only, as far as the life of locomotive cranks went, in their infancy, and, if the wishes of the president and some of his colleagues in the House were carried out, possibly they would not have an opportunity of finishing them. The author had taken part in the discussions at a good many meetings at which the question of impact had come up. He desired to thank him very sincerely for the very fair way in which he had dealt with the impact question in the present paper. He had not always agreed with the author in times past, but there was very little to take exception to in regard to what was said of impact tests in the present paper. He desired to quote a few words from some remarks made by the author in the discussion of Major Philpot's paper before the Institution of Automobile Engineers. "It is clear that the energy absorbed in breaking an impact test-piece is the result of work done above the elastic limit of the material." That brought him to the last point he desired to make, to which he thought some attention ought to be given, namely, that a large number of structures had to bear stresses beyond their elastic limit. The knowledge which would be derived on that subject from the author and other investigators who were doing such great work in this country might throw some light on that subject, which would help very materially in the future.

Major H. P. Philpot, R.A.F., did not entirely agree with the paper, although there were many points in which he was very much in agreement. In the early part of it the author put on to Professor Unwin the statement practically that the elastic limit was the only thing that an engineer seemed to be concerned with. That was the sort of attitude which he understood the author wished to put into Professor Unwin's book on the subject. He thought engineers must confess that in design work they used the elastic limit practically entirely in their calculations, but they believed that some of the other characteristics of the material had very considerable influence upon the life of the part. They could only use the elastic stress limit in calculation, because they were unable to calculate from any of the other features any useful property in connection with the loads. At the moment he would like to put forward the opinion that, while the elastic limit was the prime factor which the engineer used in design, the elongation, reduction of area, and even the notched-bar test were factors in the life of the part. The author stated that high impact steel was not impervious to disastrous failure due to existing cracks of considerable sharpness. He entirely agreed with that, but he thought it might be said that that high impact steel was probably less likely to fail than a low impact steel from a point of view which he desired shortly to place before the members.

With regard to the Charpy test the author had shown that the test gave a different ratio between the brittle and non-brittle conditions from the Izod test. That was an influence which was due to the radius at the base of the notch. The larger radius at the base of the notch always tended to mask

Fig. 1.



Series.	Bar.	Diameter of Test-Piece.	Limit of Proportionality.	Yield.	Ultimate Stress.	Elongation.	Reduction of Area.	Average Izod Value.
		in.	tons p. sq. in.	tons p. sq. in.	tons p. sq. in.	p.c.	p.c.	ft.-lb.
	1	.399	27.2	44.0	59.6	22.7	60.1	62.5
XXXIII	2	.400	28.7	43.0	58.1	22.7	56.7	19.2
	3	.400	31.9	45.8	61.1	22.7	59.4	60.2
	4	.283	28.0	48.8	59.6	24.0	59.5	10.9
XXXIV	5	.424	29.0	47.2	61.5	23.3	61.0	54.4
	6	.423	29.0	45.5	59.1	23.3	60.4	56.2
	7	.424	28.5	44.8	55.9	24.7	63.8	58.3
XXXV	8	.399	26.0	42.0	55.0	23.3	62.3	56.4
	9	.399	32.0	44.5	56.0	22.7	58.9	32.1

Bar 1. Nickel chromium steel, overheated, then incorrectly treated.
Bar 5. Nickel chromium steel, overheated, then correctly hardened and tempered.
Bar 6. Nickel chromium steel, overheated, then correctly tempered only.
Notches same shape as in standard Izod test piece, Type A, and Charpy test piece Type S.
Span 44 mm. Loaded at centre of span.
Energy absorbed, Bar 4. 7·55 and 9·11 ft.-lb.
Energy absorbed Bar 5. 41·4 and 42·7 ft.-lb.
Energy absorbed, Bar 6. 44·8 and 42·7 ft.-lb.

Fig. 6.

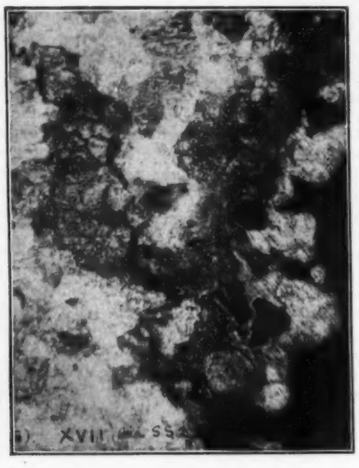


FIG. 2.

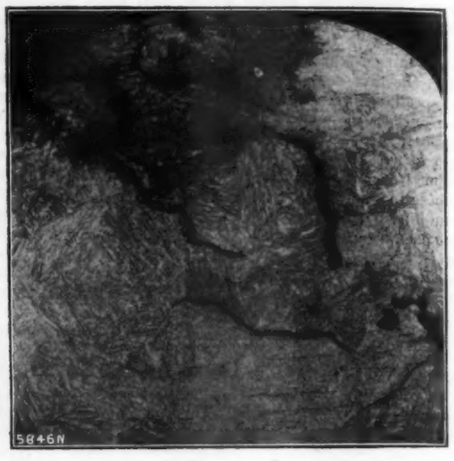


FIG. 3.

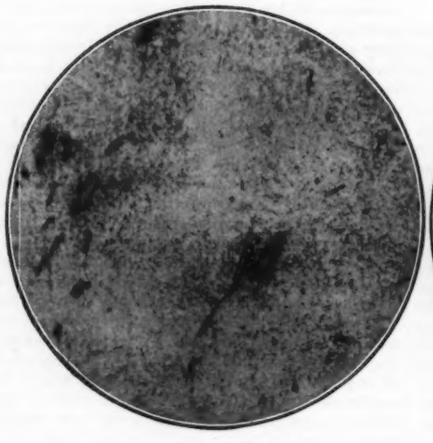


FIG. 4.

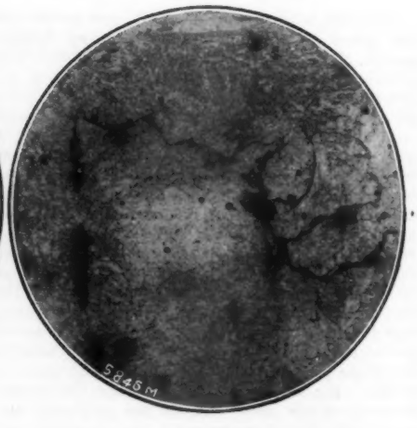


FIG. 5.

the effect of what might be called notch brittleness. The author also referred to some notched-bar tests in which he mentioned the energy required per square centimetre. He (the speaker) desired to protest against the expression of notched-bar tests in terms of the energy per square centimetre. It meant nothing, because it was in dimensions which did not give the properties of stress. He did not understand why the energy per square centimetre could be held to be of any particular value. If there was an energy to be expressed in terms of the dimensions of the part, it should be energy per cubic centimetre or some other factor of the dimensions of the test-piece. The author stated that the notched-bar test did not give elastic range. He was convinced that this was correct. The notched bar test did not give any indication as to what the elastic range of steel was; in fact, in many tests he had made he found that the notched-bar test was quite independent of the tensile values. The author mentioned this point—that the tensile test failed to give the differences which were produced in the notched-bar test.

Reference was made in the paper to a suggestion which he (Major Philpot) made in his paper read before the Institution of Automobile Engineers, as to why it was that a nickel-chrome steel should give when slowly cooled a low notched-bar value, although it gave practically identical values on the tensile test throughout the whole range of values which were measured. He did not feel that he could quite accept the author's proposition any more than the author accepted his. If the quenching after tempering produced what he called a meta-stable condition, one which was objectionable compared with the condition which was introduced by slow cooling, why was it that none of the tests which were made seemed to give a reflex of that unstable condition in the high tensile test-piece? He did not see why there should not be some reflex of that value in the value obtained. From Fig. 1, which was taken from his paper read before the Institution of Automobile Engineers, it would be seen that there was quite a large number of values for the tensile tests, and the limit of proportionality. The values were very similar, and the yield, the ultimate stresses, the elongation, and the reduction of area, were also very similar. As the table showed, the Izod impact value for quick cooling was 63·5; slow cooling, 19·2; rapid cooling, 60·2; slow cooling, 10·9, &c., very variable values, while the tensile test results were very nearly similar to one another. There was one case in which rather a different condition was obtained, as follows:—

Limit of Proportionality.	Ultimate Stress.	Elongation.	Reduction of Area.	Impact Value.
34·8	59·3	26·0	61·9	62·1
34·8	60·3	23·0	44·3	8·0

These results were from the same steel in what were called a tempered brittle condition and a non-brittle condition. The impact value was the average of quite a number of tests, from six to eight in each case. If the steel in the condition in which it was quenched after tempering was in an unstable condition, why was it that the only values where there were differences between those two were detrimental to the stable condition rather than to the unstable one? The elongation, reduction of area, and impact followed one another in this particular case, while in Fig. 1 there were very nearly identical values throughout.

Fig. 2 showed some of the secondary cracks that took place in an impact test-piece when it was broken. The surface of the fracture was on the left-hand side, where there were one or two little islands something like the grains of the steel standing out in the copper which was deposited in order to preserve the edge of the fracture. The auxiliary fractures appeared to follow around the grain boundaries. That was why he thought the suggestion he made was perhaps a reasonable one. In Fig. 3 it would be seen that they seemed to follow round the edge of what might be called the main grain in the steel. These figures were both from impact pieces which were tested in connection with his paper. Fig. 4 presented an example of the beginning of a fatigue fracture. There was a small inclusion in the steel and starting from the lower edge of the inclusion there was a crack beginning and coming downwards. The width of the inclusion measured on the microphotograph would probably be $\frac{1}{10}$ in., and the magnification was 300 times on the original, so that the distance across represented about $\frac{1}{3000}$ in. If the mechanism of the fracture as it took place was imagined, he thought it would be quite clear that as the fracture started it was quite possible that a short length of material was subjected to over-stressing in the bending to an extent such as to exceed the characteristic point where fracture occurred in a brittle material. Fig. 5 depicted a similar crack which had apparently when started, branched out, as it was further developed in several directions.

Fig. 6 showed the results of slow bending tests upon notched bars. They were not impact tests, but were made slowly in a hydraulic machine. In the brittle condition the diagram showed how the bar gave way. The bending load was applied upwards and the reflex horizontally. The first curve was of a brittle specimen which fractured soon after the elastic load was passed. The figure also showed a second one from the same test-piece. In other cases the figure showed the bar bent over, and took a considerable amount of work before it would ultimately fracture. He offered the suggestion for the author's consideration that, in connection with the life of a crank shaft which was subjected to bending what was more or less in a notched form, and which might include an inclusion such as had been shown on Figs. 4 and 5, if, during the life of that crankshaft, it was subjected to a shock which the designer did not expect, say, from back-firing or something of that kind, that shock might possibly be absorbed by the specimen. If the shock only produced a local effect, it might be absorbed by the specimen without any fracture or any increase of defect, while otherwise it would probably break off short. The fractures of the specimen of the tempered brittle condition in Fig. 6, when bent in a slow bending machine, were exactly similar to those obtained from an impact machine. The specimen actually flew out of the pressure machine, as though it had been struck with a blow, although the load was a dead load produced by hydraulic pressure.

Sir Robert A. Hadfield, Bart., F.R.S., said the paper proved that there was a good deal more to be learned in regard to notch testing or nick testing. The method of carrying out the test was very important. He had ventured to bring the subject before the notice of the Institution of Civil Engineer in his Forrest lecture of 1906, and he was very sorry to say that since that time, no other Frémont impact testing machine had been used in this country, That was very unfortunate, because if the Frémont machine had been used a uniform system of carrying out nick tests would have been introduced, which from his own point of view would have been superior in every possible way; in fact, it might have been the first wedge by means of which the metric system could have been introduced. He did not support the metric system as a whole, but for scientific purposes they were so accustomed to using metric measurements that it would have been a very good plan if it could have been adopted for shock tests. He believed the adoption in France of the Frémont testing machine was largely the reason for the wonderful progress that had been made in that country in the manufacture of special alloy steel. He did not mean to say that a great amount of work was not also done in England, but in regard to the application of alloy steel to automobile construction there could be no doubt about it that this country was very much indebted to France.

Turning to the paper, he thought the case of the St. Neots rail was due to the presence of cracks. He wished the author could find a specimen of brittle steel which was really perfect so far as being free from cracks was concerned. In that case he could not help thinking that the shock test, and especially the Frémont shock test, would bring out the qualities, good, bad or indifferent, of the sample. He spoke very strongly on that point, because he had had to go through the mill of experience in the making of various tests. Some years ago he made up his mind that he could produce in his own works cast material which would give as good results as forged steel. That was a very heroic attempt, and perhaps he expected rather too much, but a very high quality of material as a cast product had now been obtained, and the development had been largely the result of the aid given by the Frémont machine. He desired to refer to the question of the velocity of impact. The particular products of his firm were subjected to gunfire in connection with which there was the highest degree of velocity, in many cases up to 2,000 ft.-seconds, or even more than that. He remembered being present at the proving ground when a specimen of very fine cast material, which it was thought would give excellent results, went to pieces at the very first blow. But his firm were not discouraged; they went on with the work, and he was glad to say that they and others had been able to produce during the war cast products which would stand gunfire. The monitors which were used during the war for attack on the Belgian coast were furnished with conning towers which were a cast product. The Germans never succeeded in hitting one of those conning towers, so that it had not been proved in action whether the towers would stand the test or not, but of course, exhaustive trials were carried out on the proving grounds and it was quite certain that the material was satisfactory in every respect.

He heard someone who had been reading the paper remark that he thought the author was trying to prove that shock tests were no good or not of the greatest value, but personally he was quite sure that that assumption was wrong and that the author had not that idea in mind. He (Sir Robert) might exaggerate the value of shock tests, but he could not help thinking that they were a very important adjunct towards ensuring the use of the very best quality material. He hoped he would be forgiven for referring again to his Forrest lecture, but it proved one of the facts which had been brought out by the paper. He took a sample of mild steel and embrittled it; it was tested in the Frémont testing machine, and its value was shown to be only about 1½ kg. to 2 kg., which meant it was a very unsafe material. The same specimen without any nick in it was submitted to exactly the same shock test and it bent double cold. In that particular case they had not enough velocity. He was quite sure that if they could have taken the same bar without a nick and submitted it to a blow of sufficiently high velocity they would have found out its brittleness. In that respect he did not agree with the conclusion of the author. He was very glad to see that his friends Dr. Stanton and Major Philpot were paying special attention to the question of velocity; they had both obtained very valuable results which he hoped it would be possible before long to place before the members.

He was delighted to note that the author referred to a study of the ultra-microscopic arrangement of metals. He hoped the study of the ultra-microscopic arrangement would be followed up, because he believed much would be learned from studying structures at very high powers. Metallurgists were now beginning to understand structures at lower powers of perhaps 1,000, 2,000, or even more; but he thought it was necessary to go still further, and he hoped someone would take up that particular line of research. He thought there was one omission from the very important Table II in the paper. If the author would add the composition of the various steels in that table it would prove of great value, because one could hardly judge of a sample of steel without knowing its full composition. A tyre might contain a little more sulphur and phosphorus than was usually the case, and that might possibly be the reason of the shock tests being lower than they should be. He did not say that was so in the present case, because he presumed the author had satisfied himself on the point. In conclusion he hoped the president would pardon him digressing by mentioning that a great deal of excellent work had been done in reference to notch testing by the International Testing Association. That association had come to an end, owing to the war. Professor Howe had the matter in hand, and if the Institution of Mechanical Engineers and other technical institutions could see their way to giving him a little help

he thought it would be very desirable that that should be done, in order that the allied nations might pull together and not allow the International Association to fall to the ground.

Dr. F. C. Thompson said he would be glad if in Table II the author could see his way to incorporate the actual temperatures at which the tempering was carried out. The curve of the Stanton test figures to which the author had referred was of very considerable interest. As he presumed the majority of the members knew, steel, similar to that used, in a hardened condition, had a true elastic limit which was very low indeed. As that steel was tempered at comparatively low temperatures, the true elastic limit began to rise, and at a temperature of 300 deg. to 400 deg. C. attained a maximum. Tempering at still higher temperatures resulted in the true elastic limit falling again. If the Stanton curve was looked at, it would be found that exactly the same course was followed. Comparatively speaking, low in the first place, it rose to a maximum which corresponded as far as one could tell more or less with the maximum of the true elastic limit, and from that point it fell again. The Stanton curve in that particular case was very nearly a reproduction of the true elastic limit, a fact which the author pointed out. If that was correct it certainly seemed that the form of apparatus used by the author was not very satisfactory for the purpose in view. Something beyond the elastic limit was under consideration, and if that type of test gave nothing more than the elastic limit itself it seemed that, to a considerable extent, the time and expense spent on that particular type of testing were not justified.

The Arnold test was referred to several times in the paper, and, as he (the speaker) had had a somewhat unique opportunity of studying that test during the last twelve years, he would like to make reference to the points raised. The curve of the Arnold test, in Fig. 21 of the paper, was remarkable. It would be seen that in the hardest condition the steel withstood 300 reversals. That was an extremely high figure for a material of that kind so treated, and he believed the result surprised Professor Arnold himself. When it was pointed out that 300 was the figure which a mild steel was expected to stand, it would be understood that to obtain something like the same figure from a hardened nickel-chrome steel was an achievement of considerable importance and spoke very well indeed for the material. It would be seen that as the Brinell number fell, *i.e.*, as the temperature of the tempering was increased, the Arnold figure fell at first to a minimum. That minimum corresponded to a Brinell number of 350, which, as far as one could judge in the absence of actual tempering temperatures, would be somewhere about 400 deg. C. A temperature of about 400 deg. C. was one which, as far as possible was, he believed, steered clear of by manufacturers, and in confirming that practice the Arnold test once again justified its existence.

Another point with regard to the alternating test arose in connection with the figures referring to the fractured angle-iron, in which a 0·09 carbon steel gave an Arnold figure of 211 reversals, which the author considered a satisfactory figure. As a matter of fact, it was not by any means a satisfactory one. It amounted to only some 60 per cent. or so of what a steel of that character should have stood—300 to 350 would have been the normal figure—with the result that 211 reversals indicated that the particular steel was in a distinctly brittle condition to start with. The next point he desired to deal with in connection with the Arnold test was that it would be seen in the figures near the end of the paper that two pieces of an identical steel, treated in one case to be tempered brittle and in the other case to be tough, gave identical Arnold values, while the impact values were different. From that the author drew the conclusion that, since the Arnold test showed that there was no difference between the two, the impace test was therefore unreliable, and a brittleness shown only by that test was characterised by the author as simply apparent brittleness. In comparing those two sets of figures, he wished to make the point that the Arnold test piece was unnotched. It was well known in connection with tempered brittleness, as Major Philpot had already pointed out, that the notch itself played a very important part. It therefore hardly seemed to him justifiable to compare tests on an unnotched bar with other tests on notched bars. If the author could carry out similar Arnold tests on a notched bar, the notch being similar to that used in the Izod test, very valuable results must follow; and if under those circumstances with a notched Arnold test bar he was able to show that there was no difference between the two, his position would be very strong indeed.

There was a further point he would mention. The author suggested that a high impact value should, according to the upholders of impact tests, result in fracture not occurring. The author said twice that fracture should be prevented. Personally he thought that was hardly the position. Obviously it was impossible to prevent fracture if the elastic limit was exceeded in dynamic conditions, whether the impact value was high or low. If the impact value was high, then the rate at which the fracture proceeded would be low, and under those circumstances it was quite possible that the flaw would be detected before it led to disastrous effects. On the other hand, if the impact value of the steel was low, the rate at which the crack would be propagated would be distinctly high, and under those circumstances fracture would proceed so rapidly that there would be little chance of detecting it. It was not a question of whether fracture could be prevented by high impact value; the point was whether it could be delayed to such an extent that one had a reasonable opportunity of detecting it before disaster occurred.

The President said that the normal time for closing the meeting had arrived, but there were a number of speakers still on the list and the discussion must be adjourned to the following meeting. He asked Dr. Hatfield to reply briefly before closing.

Dr. W. H. Hatfield said it was impossible to reply fully at the moment to the different points which had been raised, but he would deal with them in detail later. He desired to take the present opportunity, however, of replying to Professor Howe's remarks, as he did not know whether that gentleman would be in this country a month hence. One of the most interesting points raised by Professor Howe was the definition of "brittleness." When writing the paper he thought someone would be sure to ask what the word "brittleness" meant, so he looked it up in the dictionary, and found that "brittle" meant "apt to break," "easily broken," the origin of the word being *brytan*, Anglo-Saxon for "to break." He put it to Professor Howe that that was a concrete definition which left them in no doubt as to what was meant by the word. He ventured to suggest that they could both go back to the Anglo-Saxon and be content with that derivation.

The meeting then terminated. The discussion will be resumed at the meeting to be held on Friday, May 30th.

STEEL WORKS MACHINERY.

*Notes on the Development of Steel Works Machinery.**

By Mr. T. W. HAND, Chief Engineer, Messrs. Davy Brothers, Limited.

(*Concluded from page 569.*)

ROLLING MILLS.

ALL metallurgists are aware of the important extensions being made and the many new plants which are being laid down to increase our production of basic steel, and as the author has been closely associated with many of these plants in connection with the rolling-mill machinery, it is possible to give a brief description of some of the leading features of construction.

What strikes the visitor to an up-to-date mill is the very rapid development which has taken place in electrical operation of such machinery, and it may be of interest to explain that whilst great developments have taken place in this country, a very large plant capable of rolling down 8,000 tons to 10,000 tons of ingots per week into billets, rails and structural shapes generally, is at present being installed at the Caen Works in Normandy, in which electricity will be the only motive power used, no steam or hydraulic service whatever being provided in the mill installation.

Until quite recent years, much difference of opinion existed in this country regarding the relative merits of steam or electric drive for large reversing rolling mills, it being then a generally accepted theory that electric driving was scarcely a commercial proposition except in certain favourable localities where electricity could be generated at very low cost by the use of blast-furnace gases with internal-combustion engines.

Curiously, however, few of the steel works having gas engines in successful operation had adopted the electric drive at this time.

Time will not permit of further consideration of the large power gas engine. This has, moreover, formed the subject of many valuable papers, and it is, of course, well known that users' experience has been so varied that considerable difference of opinion still exists amongst well-informed engineers regarding its adoption.

It should be remembered, however, that quite twice the amount of energy is recovered by utilisation of gas in internal-combustion engines than is possible by making use of the gas for firing steam boilers, and this knowledge alone will no doubt provide the stimulus to the engineers' final victory over such disappointments as have so far been experienced.

Another source of energy by no means newly discovered has, however, been somewhat rapidly developed during recent years, and has opened up great possibilities regarding the electrical operation of rolling mills at our large steel works.

The energy referred to lies in the chimney gases from steel melting furnaces, and whilst recovery of heat from this source has formed the subject of much controversy, pioneer work has been steadily proceeding, and actual data is now available which clearly demonstrates the possibility of recovering sufficient energy by the installation of waste heat boilers to roll down the whole of the steel melted.

It is often said that with a well-designed melting furnace the chimney gases contain no more heat than is necessary to create draught, but such conditions are seldom realised, and in a most interesting paper read by Mr. T. B. MacKenzie last year before the Iron and Steel Institute, it is clearly shown that 1,000 lb. to 1,200 lb. of steam per ton of ingots produced by the furnace is quite readily obtained. This steam, if used in high-class turbo-generators, would develop about 70 kw.-hours.

Still more recent tests of installations on the North-East Coast where boilers with greater heating surface are in use quite substantiate Mr. MacKenzie's figures, the actual results showing about 95 kw.-hours per ton of ingots produced from hot metal charges with a consumption of 6¼ cwt. of fuel in the producer. Adding to this 10 per cent. to 15 per cent. as quite reasonable additional energy to be obtained from installation of boilers on soaking pits, it may be confidently assumed that 100 kw.-hours to 110 kw.-hours may be recovered per ton of ingots produced on a well-arranged plant.

With the electrically-operated mill, it is, of course, quite easy to determine the power consumption per ton of steel rolled, and the following figures may be taken as maximum power requirements for commercial production of sectional material:—

20 kw.-hours per ton: Cogging.
40 kw.-hours per ton: Finishing.
20 kw.-hours per ton: Direct mill auxiliaries.
20 kw.-hours per ton: Indirect mill auxiliaries.

100 kw.-hours per ton: Total.

One of the steel works recently laid down in the North of England, when completed, will comprise eight 60-ton open-hearth furnaces, two 400-ton mixers, soaking pits, 40-in. cogging mill, light section mill, also large mill for heavy sections and rails. On this plant waste heat boilers are installed on all melting furnaces, mixers and soaking pits, and the mills will be electrically operated throughout.

The weekly output of this plant when fully at work will be 5,000 tons of ingots each of 3 tons weight, and as the whole output will pass through the 40-in. cogging mill, the author proposes to describe this in some detail as a typical example of modern mill practice.

The ingots are cast on cars, and after stripping are conveyed on trucks to the soaking pits situated at the end of mill buildings. The ingots are withdrawn from the pits by crane and deposited directly into tilting chair at outer end of mill approach tables which convey the ingots to mill.

The tilting chair is of the well-known hydraulically-operated type, but Fig. 6 represents a chair of somewhat different type used on the all-electric mill referred to earlier in this paper, the operating motor (not shown) coupling directly to the worm shaft. An advantage of this latter method of operation is the automatic retardation derived from the crank motion. The construction of chair frame is also interesting, this being so designed that either large or small end of ingot may be presented to the rolls by simply turning the chair to right or left as required. Fig. 7, Plate XLVII, shows the 40-in. cogging mill, the view being taken from the delivery side of the mill, the tilting chair at far side of mill not being visible. The mill is operated by direct-coupled reversing motor receiving current from a motor generator set with flywheel for meeting the peak load, and may be justly claimed to be both mechanically and electrically one of the finest installations in existence, the best practice of all countries being embodied in view of the high output contemplated, viz., 45 tons of 4-in. billets per hour. On larger sections, say, 6-in. blooms, the full capacity of such a mill is seldom reached owing to limitations in the steel supply, but assuming regular feeding, it may be safely said that an output of 10,000 tons per week could be readily obtained.

The electrical equipment of the plant comprises the following machines of the Westinghouse type:—

Reversing mill motor of 13,700 h.p. maximum (double armature).
Three generators, each of 1,500 kw. capacity.

* Paper read before the Sheffield Society of Engineers and Metallurgists.

An induction motor of 2,700 brake horse-power capacity.

The synchronous speed of this motor is 600 r.p.m., and its direct-coupled flywheel weighs 30 tons and has a peripheral speed of 375 ft. per second.

The supply current is three-phase, 60 periods, 2,400 volts. Separate machines are provided for exciting the motor, generators and main exciters.

The main mill motor will develop constant torque up to 50 r.p.m. in either direction, beyond which speed the torque diminishes as the speed increases up to 100 r.p.m., the horse-power remaining constant at 13,700 maximum. The whole manual control is effected on the Ward Leonard system by a single hand lever, the central position of which corresponds to standing conditions, whilst movement in forward or backward direction speeds up the motor in either direction as may be desired. A feature of the equipment is the very rapid acceleration of the mill motor, this being capable of 30 reversals per minute up to a speed of 32 r.p.m. These quick reversals are obtained by forcing the generator field for a limited time during the acceleration period, the voltage impressed on the fields for this time being much greater than normal, a relay connected across the main armature connections serving to restore normal conditions when the voltage in these leads has reached a predetermined value.

The Ward Leonard controller operates on the fields of the exciters and not on the main generator fields, thus greatly reducing the amount of current to be handled and permitting a quite small and compact controller to be used. An automatic slip regulator of the liquid type is provided for the induction motor of the generator set, the mechanism operating the weir of the regulator being so arranged that its position is continuously adjusted to give the required change of slip, thus allowing the flywheel to give up energy and prevent the normal demand on power station being exceeded.

Turning now to the mechanical side of the plant it should be at once explained that the essential conditions of design were in order of importance, adequate strength, liberal bearing surfaces, close machine finish, thorough provision for efficient lubrication, and ready accessibility of all working parts. The separate photographic views on Plates XLVII and XLVIII illustrate the manner in which these conditions have been realised. Fig. 8 shows the mill train as seen from the driving end and indicates clearly the design of main coupling. This is of the fluted type having multiple driving faces at large radius, thus ensuring ample driving surface, the flutes being machine-cut without clearance to ensure correct engagement and eliminate back lash. The heavy rotating parts are carried by a spring-supported bearing and hydraulic shifting gear is provided to allow of disengagement of mill when motor adjustments are being made, &c. Mill-driving pinions provide serious study for both engineers and metallurgists, as owing to the enormous load transmitted, skilful design is essential, and the long life which commercial considerations necessitate warrants the very best material available being used in their construction. The requirements are somewhat antagonistic, a hard surface being essential to resist wear, whilst absolutely safe material is required to withstand the frequently-applied reversing load which will introduce heavy shocks if wear is allowed to take place between the engaging teeth.

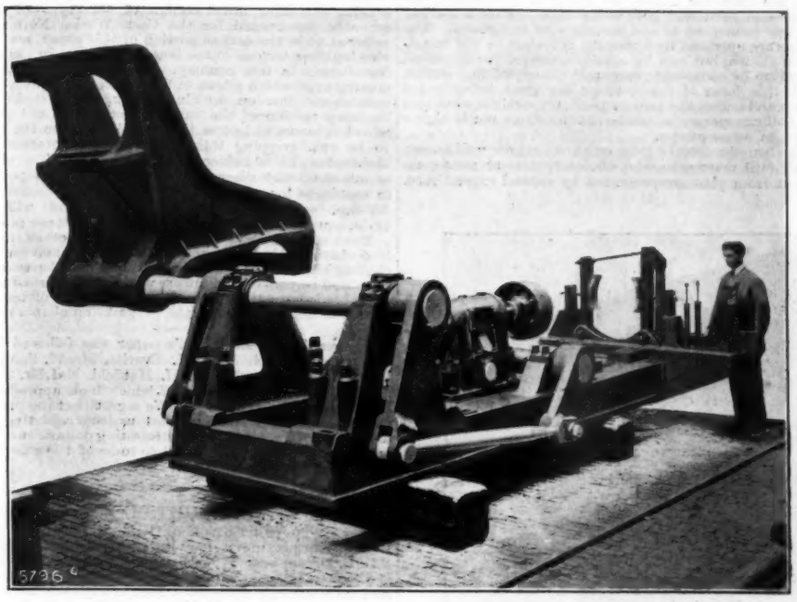


FIG. 6. HYDRAULICALLY-OPERATED TILTING-CHAIR.

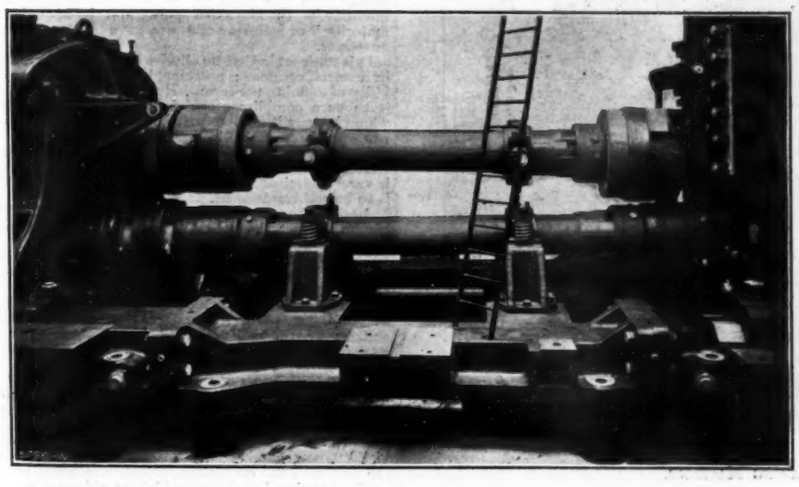
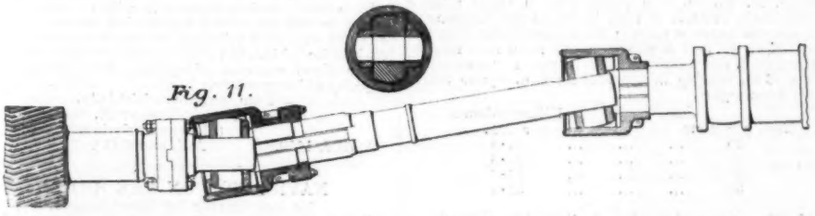


FIG. 10. TOP SPINDLE OF COGGING MILL.



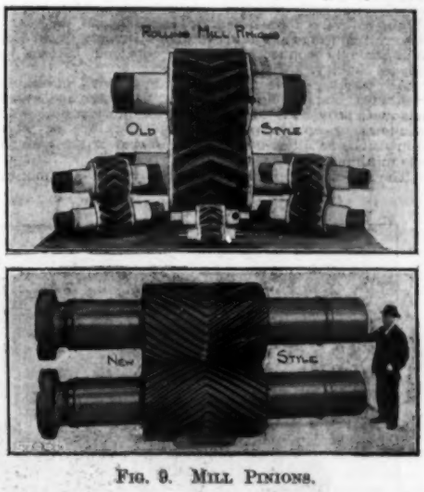


FIG. 9. MILL PINIONS.

Of the materials so far used, cast-steel containing 0·65 per cent. carbon has given good results for pinions of such size as can be cast in a single piece, larger pinions being built up by shrinking nickel-chrome rings on to forged centre shafts. The lower illustration in Fig. 9 shows a typical modern cast steel mill pinion, the actual dimensions of this being as follows :—

P.C. diameter	40 in.
Face width	5 ft. 3 in.
Pitch	4 in.
Overall length	14 ft. 6 in.

The upper illustration shows a pinion having machine-moulded teeth and of general proportions such as were formerly adopted on similar sized mills of older construction. The face width of this latter is 33 in. and the pitch of teeth 7 in., there being two teeth in engagement as compared with five with the finer pitch.

The relative efficiencies of transmission may be taken as 98·5 per cent. for the modern and 87 per cent. for the old style pinion, and the working life under conditions of mounting such as would be provided in each case as about 3 to 1. Needless to say, modern machine-cut pinions require suitably mounting, their housings being massive, rigidly secured to the foundation beds to resist the overturning tendency, and built in such a way as to completely enclose the pinions and allow of these latter being flooded with lubricant both in teeth and journals.

In the mill illustrated about 20 gallons of oil per minute is fed through the system by means of a separate motor-operated pump, an alarm bell being fitted in circuit to ring in the event of oil supply failing. In a modern mill the connecting spindle between upper pinion and roll requires careful consideration, and the design adopted must permit of constant area of driving surfaces for all possible positions of working. Such spindles are now made of relatively great length to reduce the sliding movement of driving faces, the engaging ends being constructed on universal joint principle to allow of angular working.

Fig. 10 shows the design of the top spindle of the mill now under review, this being of a type much used in America and already installed on several of the armour-plate mills in this country, the proportions being, however, suitably modified to ensure long life. Referring to the figure it will be observed that each jaw end carries two semi-circular bearing blocks which engage with flat faces in the opposing jaws, thus forming a complete gimball arrangement at each end of the spindle.

Fig. 11 shows another design of universal spindle originally introduced by Mr. Henry Crowe for use on the 36-in. cogging mill at the Skinningrove Iron Company's works, and now being made for a somewhat

similar mill at present under construction. With this type the driving blocks are rectangular and mounted on gudgeon pins, the blocks swivelling on their pins and the opposing coupling-box sliding over the flat faces of the blocks during angling of the spindle.

Referring to Figs. 7 and 12, Plates XLVII and XLVIII, it will be seen that the spindles are balanced through compensating levers carried on a spring suspension at the one end and connected to roll balance cylinder on the housings. This combined roll and spindle balance requires one hydraulic ram only, a feature which will no doubt be duly appreciated by maintenance engineers. The roll housings are steel castings with widespread feet and strongly connected together top and bottom to ensure rigidity.

All working surfaces are machined with minimum clearance compatible with free working and very adequate provisions are arranged for lubrication. The windows or openings through housings are of wide dimensions to allow of endwise removal of the rolls in the minimum of time.

The roll-screwing gear is operated by a 100-h.p. motor, a slipping clutch being interposed as a safeguard against over-running in view of the rapid screwing speed adopted.

The feed roller gear of this mill warrants some consideration, inasmuch as apart from its massive proportions all driving mitres are totally enclosed for running in oil and the shaft journals provided with ring lubrication.

Doubt has been expressed as to whether such refinement of construction as that just described is really warranted in rolling-mill machinery, but when it is realised that stoppage of a mill plant with a normal output of 4,000 tons per week costs about 20*s.* per minute, the somewhat widespread belief that less efficient means of power transmission are good enough for mill service should be easily dispelled, and reflection convince the most doubtful mind that continuity of operation can only be ensured by elimination of shock and wear consequent to backlash and badly fitting transmission surfaces. So successfully has this been accomplished on the mill under consideration that even when rolling at maximum speed the whole plant operates with remarkable silence.

Not the least important feature of this mill is the universal manipulator, this being the first of the type to be installed in this country. On examining Fig. 7, Plate XLVII, and Figs. 12 and 13, Plate XLVIII, it will be observed that long power-operated guides are provided back and front of the mill. The back and front guides are mechanically coupled in such manner that when the guides are brought together at one side of the rolls to guide the entering piece the similar guide at outgoing side will be in exact position in line for receiving the piece when leaving the rolls, thus ensuring this being delivered perfectly straight and already under control for quick transfer to next pass.

The ingot-tilting mechanism is attached to one of the guides at the entering side of the mill, this being clearly shown on Fig. 12, Plate XLVIII. It will be observed that the turnover fingers are electrically operated, the motor and reduction gear being mounted on a trailing carriage connected to and moving with the guides. The guides are operated by hydraulic cylinders in the installation shown, but can be readily arranged for electrical operation by connecting motors to the equalising shafts. With this form of manipulator the piece being rolled enters and leaves the mill in perfectly straight condition and rolling operations can be conducted at much higher speed in consequence.

The benefits derived from quick-rolling are well known to all mill managers, who obviously aim at maximum output from plants represented by capital expenditure.

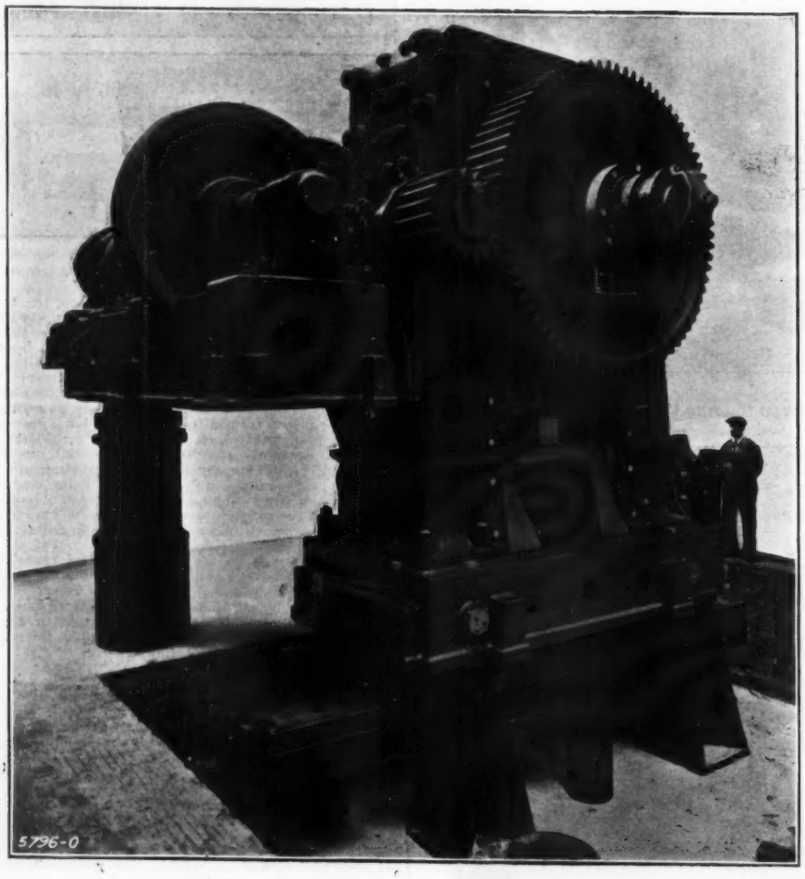


FIG. 14. VERTICAL SHEARING MACHINE.

This aspect of the subject was very ably expressed in a recent paper read before the Cleveland engineers by Mr. G. M. Brown, who states that in many mills a considerable amount of time is lost in the handling of the material between passes; and the extent to which this may affect the cost of power for the main rolls may be judged from the following table of power consumptions for a 36-in. cogging mill producing 6-in. square billets from 3-ton ingots.

Tons per Hour	Kilowatt-hours per Ton.
75	24·5
60	25·5
45	27·7
30	32·6

Needless to say that when dealing with such outputs manual labour around the mill floor is quite inadmissible, and from further reference to Fig. 7 it will be seen that on the plant already described the whole of the rolling operations are controlled by three operators on the control bridge.

In a modern plant the auxiliary machinery beyond the mill, such as shears, saws, &c., requires very careful consideration in order that output may not be restricted by any bottle neck at this point. At the mill just described electrically-operated horizontal shears are installed. This type of shear is well adapted for blooms or billets, as the horizontal method of cutting eliminates such complications as deflecting tables in the roller gear, and although the shear generally occupies considerable floor space, much advantage is derived from the ready accessibility of all working parts which the horizontal construction provides. The shear under consideration is designed for cutting 10-in. square blooms down to 4-in. billets at speeds of 6 and 18 cuts per minute respectively.

For certain sections, particularly wide flats, the vertical type of shear is more suitable, Fig. 14 representing a rather novel design of this type of shear recently constructed for the Caen Works, Normandy, referred to in the earlier portion of this paper, and now also building for one of the large mill plants in course of installation in this country. The shear is of the up-cutting type which allows of fixed roller tables, and is so constructed that on the clutch being engaged the preliminary motion of the camshaft on which the clutch wheel is mounted lowers the top blade on to the piece to be cut, gripping this whilst further rotation lifts the bottom knife holder to effect the cut. The clutch is automatically disengaged on reaching top position in readiness for next cut. This shear is operated by a 200-h.p. continuously-running motor, and will cut 10-in. square blooms at the rate of 15 strokes per minute.

Time will not allow of further survey of other equally important sections of steel works plant, and in concluding the author wishes to express thanks to those firms and responsible engineers who have furnished much valuable information, and also to members of his own staff who have assisted in the preparation of this paper.

The reading of Mr. Hand's paper was followed by a discussion in which Mr. C. K. Everitt, Mr. W. F. Mylan, Mr. Walter Carter, Dr. W. H. Hatfield, and Mr. Parry took part, and in the course of which high appreciation of the paper was expressed. We regret that the present demands upon our space prevent us from reporting this discussion, as it raised many interesting points connected with steel works practice; but to some of these we hope to refer on a future occasion.

DRAUGHTSMEN.

TO THE EDITOR OF ENGINEERING.

SIR,—Permit me a few lines for a brief reply to "O. L. D." on page 579 of your last week's issue. If he is a draughtsman he should be more precise in his phrases, and more accurate in his data, and, in any case, he should not be contradictory in his suppositions. In his first paragraph he thinks that those who are slumbering peacefully in the boat which is rushing towards the rapids, "in the point of actual numbers are in the minority." In his third paragraph it is "the vast majority" of members who will have become Bolshevist unawares.

It is noticeable that he alludes to "advanced leaders" in inverted commas; presumably to escape the responsibility of defining the term. He certainly does not intend it to be a complimentary description of those against whom he uses it, and yet, if it has any accuracy at all, it can scarcely be otherwise.

To be the pioneers of thought, and policy—to be the thin end of the wedge (which usually suffers in the impact), is surely admirable, while to admit yourself reactionary is to be self-condemned.

Again, the executive, whom he appears to think responsible for the policy of the association, is merely an administrative committee, as its name denotes. The policy of the association is settled at the National Conferences, and on all important matters the delegates come instructed by their branches as to how they shall cast their card vote. This is a democratic method, but we go farther. On vital matters a referendum is taken, and, so far, the real policy of the association has been settled by overwhelmingly large votes in favour of the proposal.

Might I suggest your correspondent is a little "pre-war" in his outlook? The world has been moving rapidly, and it is time he rubbed his eyes, and looked again.

If, by "advanced ideas," he means a clearer perception of the true economic position of the draughtsman; of the nature of the contending forces in industry; of the semi-professional snobbery which so abhorred the very name of trades unionism that it checked and defeated all previous attempts at combined effort and mutual responsibility, and for which latter draughtsmen have paid so dearly during the war, he will, I venture to say, awake to find his second supposition correct, and that it is not the small minority of draughtsmen who have left him far behind, but that the policy of the association is the direct outcome of opinions held by the great majority of its members.

I am, Sir, yours faithfully,
ERNEST H. WALKER
(Chairman, National Executive,
April 6, 1919. A.E. and S.D.).

NAVIGATION ON THE RHINE.

TO THE EDITOR OF ENGINEERING.

SIR,—I have read with great interest an article in *The Nineteenth Century and After*, on the subject of the passage from Rotterdam to Bale upon the River Rhine. All interested in river navigation in Switzerland will be interested, as the article indicates the necessity of an open and international waterway from Switzerland to the sea.

I should be greatly pleased if you will allow me space for a few remarks on this subject.

When Germany up to last summer thought herself in full possession and control of this river, it was her idea to use the stretch between the Swiss frontier and the city of Strasbourg for the production of electric

power. Projects were already planned for 12 great power plants on this section of the Rhine. The consequence of such a system of hydro-electric works would have been an almost complete bar to the navigation which could only be overcome by a number of flood gates. Long ship-trains, as they come up from Rotterdam could not proceed any further than Strassbourg without great inconvenience, and much loss of time. Thus Switzerland would have been greatly handicapped in her shipping development, and would be side-tracked off the "*grande route.*" What would have been the gain to Germany? With those power plants they certainly would have been able to produce quite a number of million kilowatts yearly, but at a cost much higher than the price paid for energy from the adjoining Swiss hydro-electric plants. Therefore this proposition of blocking the Rhine with power works by Germany could not even be called a sound question of national economy.

On the other hand, "a free Rhine" would mean international welfare. The freight coming in from the high sea, could be shipped directly from Rotterdam to Bale and transmitted further to the interior of Switzerland up to the terminals of the great routes across the Alps. For a trifle more than 1,000,000*l.* the Rhine between Strassbourg and Bale could be regulated so as to secure navigation throughout the year, with the exception of a very few days.

Although the Rhine is at present the sole navigable access to Switzerland, it has competitors. On the Rhone the shiploads are brought from the Mediterranean port of Marseilles to the city of Lyons, and now there is the missing link between that place and Lake Geneva which is being studied by the experts. But on account of the difference in the altitude, large series of locks or other lifting devices are required. Therefore this relatively short stretch between Lyons and Geneva will not only involve a high cost on the navigation problem, but will afford an uncommon length of time for the passage. Another point of contact with the sea could be found for Switzerland by way of the River Po, which discharges its waters into the Adriatic. For a suitable connection between Po and the lakes cutting through the Swiss-Italian borders there would be needed great artificial channels, locks and basins. This, again, would be a great handicap to shipping. These two waterways are not yet serviceable, and it will take many years—I dare say generations—till our Alpine Republic gets her food in ship-trains from Marseilles or Trieste, and till we can send there our natural and industrial products, and then neither of those two waterways will be able to compete with a free and regulated Rhine.

It is not Switzerland alone who pleads for an open passage from its borders to the sea, it is the wish also of those countries who send their goods up-stream. England and Holland especially will fully appreciate an effective passage from their ports into the heart of the European Highlands and thence by either channel or rail—the future may show which is better—across the Alps.

I am very faithfully yours,
F. A. VON MOOS, M.E.

Lucerne, Switzerland, April 10, 1919.

THE DESIGN AND CONSTRUCTION OF VERTICAL BOILERS.

TO THE EDITOR OF ENGINEERING.

SIR,—We have been much interested in Mr. Seaton's admirable report on the work of the British Marine Engineering Design and Construction Committee, which appeared in your issue of April 18, but we feel that it is due to shipowners and other boiler buyers to correct a statement in the report which reads as follows:—

"For the vertical type of boiler there appeared to be not very special or definite rules in existence. As these boilers have been, and still are, in very general use, especially those of the Cochrane type, both for auxiliary purposes in all classes of ships and for the main machinery in smaller vessels, the committee decided that it ought to establish such rules as would ensure that these boilers shall be as safe when made in accordance with them as are the ordinary horizontal cylindrical boilers."

As far as the boilers manufactured by us are concerned, we would like to point out that they are all constructed according to the recognised rules of the various boiler authorities and insurance companies in this country and abroad, and that a complete understanding exists between us and all these authorities as to the practice to be adopted in the design of our boilers.

We maintain that our boilers are in every respect as safe as the ordinary horizontal marine type, and we can only assume that the report refers to some imitation of our boilers which the committee has come across.

Yours faithfully,
(For COCHRAN AND CO., ANNAN, LIMITED),
CHARLES E. CROMPTON, Director.

Annan, Scotland, May 6, 1919.

"A NEW THEORY OF THE STEAM TURBINE."

TO THE EDITOR OF ENGINEERING.

SIR,—I have read the series of articles, "A New Theory of the Steam Turbine," of Mr. Harold Medway Martin, in ENGINEERING, from July to September, 1918, and now, being myself interested in turbine design, I desire to signify that the theory would be complete with data if Mr. Martin could give together with curves in Fig. 7 the ratio of blade speed v to steam speed corresponding to the efficiency tests or to the value of $\frac{K}{U}$; being $K = n v^2$.

Indeed, Mr. Martin, at page 107, says that the above-said ratio is proportional to $\sqrt{\frac{K}{U}}$, but does not give any value of it associated to $\frac{K}{U}$.

I desire now to advance an objection to what Mr. Martin states at page 107, or that since velocity of steam is proportional to $\sqrt{\frac{U}{n}}$ and blade velocity proportional to $\sqrt{\frac{K}{n}}$, the expression $\sqrt{\frac{K}{U}}$ is proportional to the ratio of blade speed to steam speed; the syllogism through which he arrives at this conclusion, seems to me to be erroneous in the first proposition.

Let us consider the motion of steam through blades in which no loss for friction and impact occurs, for sake of clearness, so that equation of equilibrium of energy may be written as follows for a moving blade:

$$E U = \frac{1}{2g}(V_1^2 - V_2^2)$$

$$E U = \frac{1}{2g} V_1^2 (2 \delta \cos a - \delta^2) \quad . \quad . \quad (1)$$

$$E U = \frac{1}{2g} v^2 \left(\frac{2 \cos a}{\delta}\right) - 1\Big)$$

which are equivalent, and where V_1 and V_2 are the relative and absolute speed of steam, δ the ratio of blade to steam speed, a the exit angle of blades.

Let us now consider n moving rows of blades working in the same condition; we get from the above equations:

$$\frac{n v^2}{U} = \frac{\frac{E g}{\delta}}{2 \cos a} - 1 \text{ or } \frac{K}{U} \text{ proportional to } \frac{\frac{E g}{\delta}}{2 \cos a} - 1$$

being $K = n v^2$, which demonstrates that the ratio of speeds does not vary as $\sqrt{\frac{K}{U}}$ as Mr. Martin has stated at page 107.

The reason of this is to be found in that the steam speed is proportional to $\sqrt{\frac{U}{n}}$ only for a given ratio of speeds, so that with the variation of $\frac{K}{U}$, and consequently of δ, the proportionality of V_1 to $\sqrt{\frac{U}{n}}$ does not hold.

In the whole theory Mr. Martin does not mention the exit angle a, so I suppose he has thought to refer to turbines with normal blades for which a is about 20 deg.

Concluding, I beg you to publish this in order that Mr. Martin may clear the following points:—

Influence of exit angle on hydraulic efficiency.

Values of ratio of speeds corresponding to $\frac{K}{U}$.

I am, Sir, yours faithfully,
ING. RINALDO ZUNINO.

Cantiere Odero, Sestri Ponente (Italy),
April 13, 1919.

This letter has been submitted to the writer of the articles on "A New Theory of the Steam Turbine" and the following is his reply:—

TO THE EDITOR OF ENGINEERING.

SIR,—I have to thank you for an advance proof of Mr. Zunino's letter. I am very sorry that I cannot at present comply with your correspondent's demand for the coefficient by which $\sqrt{\frac{K}{U}}$ must be multiplied to obtain δ. As a matter of fact, reliable experiments upon nozzle and guide blade efficiencies are still lacking, and we shall probably have to await the completion of the experiments of the Nozzles Committee appointed by the Institution of Mechanical Engineers before it will be possible to comply with Mr. Rinaldo's request. It is one of the great merits of the "co-efficient system" of proportioning steam turbines (for which system we are indebted to Messrs. Parsons) that turbine performances can be compared and predicted, without a detailed knowledge of the blading losses.

As regards your correspondent's criticism, the statement to which he takes exception was, in the first instance, made in connection with impulse turbines. In this case the "carry over" is commonly small. Under these conditions the statement criticised is obviously true.

As for reaction turbines, I do not admit the adequacy of your correspondents equations, as applied to the flow of steam through an actual group of reaction blading. Consider any row of such a group. Then the energy available for producing flow through this row is

$$\Delta U + \frac{R}{2g}$$

where ΔU represents (in ft.-lb.) the thermo-dynamic head expended at this row, and $\frac{R}{2g}$ the kinetic energy carried over from the previous row.

The velocity of discharge from the row is given by

$$\frac{V^2}{2g} = m \Delta U + M \frac{R}{2g} \quad . \quad . \quad (1)$$

where m and M are co-efficients, depending on the frictional losses. The fact that M is not unity has a very important bearing on the question at issue, as your correspondent will realise if he considers the case of the flow of steam through a group when the shaft is held fast.

Expression (1) leads to an equation in Finite Differences, the integration of which (under certain assumptions) is given in my book on "The Design and Construction of Steam Turbines." From the results there arrived at, it appears that for reaction turbines $\sqrt{\frac{K}{U}}$ is closely proportional to the average ratio of blade speed to steam speed. In actual fact, with normal exhaust losses, this proportionality probably holds even more closely than would appear from the investigation given in my treatise.

I am, yours faithfully,
H. M. MARTIN.

26, Addiscombe-road, Croydon, April 24, 1919.

CRITICAL SPEED OF SHAFTS.

TO THE EDITOR OF ENGINEERING.

SIR,—We note in your issue of April 25, page 548, in a letter by Major Low, a statement to the effect that a solution of the whirling shaft problem is to be found in the *Schweizerische Bauzeitung*. We should like to direct the attention of your readers to the fact that there is no necessity to go so far afield. Work published by us during the war both by the Advisory Committee for Aeronautics and by the Royal Society will give complete solutions to the following class of problems in a form eminently suitable for the drawing office.

(*a*) Whirling of a shaft or vibration of a beam of any law of variation of flexual rigidity, with or without end thrust, and simply supported at any number of points.

(*b*) The method is directly applicable to the vibration of any propeller blade where the latter is under a tension due to centrifugal forces varying along its length.

(*c*) The determination of the crippling load of a strut with any law of variation of flexual rigidity supported at any number of points and under end thrust which may even vary along the length due to intermediate loading.

The lateral loading may be of any nature, such as that due to discs. Any one of these and similar problems may be completely solved arithmetically or graphically with extreme rapidity, especially in the more important practical cases. It is hoped to publish the results of some of these in your journal shortly.

Yours faithfully,
W. L. COWLEY.
H. LEVY.

Aerodynamics Division, the National Physical Laboratory, Teddington, Middlesex, May 1, 1919.

TO THE EDITOR OF ENGINEERING.

SIR,—In reply to several correspondents, Professor Hahn's paper can be seen at the Patent Office Library, Chancery-lane. The *Schweizerische Bauzeitung* is to be found in the top gallery section O 12—ON 48.

A letter to the editor of the journal in Zürich would obtain a copy no doubt.

It may be added here that the analysis is extended to the inertia couples. These exercise a negative or restoring moment, and give rise analytically to partial periods whose squares are negative and which are therefore themselves imaginary. Their effect seems to be small within the range of existing turbine practices, but in the case of an aeroplane with an overhung air screw of relatively great inertia of rotation the effects are possibly quite large, and the *reduction* of the critical speed may be of importance.

Yours truly,
A. R. Low.

London, May 7, 1919.

THE EXAMINATION OF MATERIALS BY X RAYS.

TO THE EDITOR OF ENGINEERING.

SIR,—In your account of the short address which I gave at the meeting of the Faraday and Röntgen Societies on April 29, it is not mentioned that the photographs which I showed were given to me by the General Electric Company, of Schenectady, New York. I acknowledged my indebtedness in my remarks, and should be exceedingly grateful if you would allow me to mention it also in your paper.

Yours faithfully,
W. H. BRAGG.

University of London, University College, Gower-street, London, W.C. 1, April 7, 1919.

SPONTANEOUS INFLAMMATION OF ETHER.—Several accidents having occurred in French ether works, E. Alilaire (*Comptes Rendus*, April 7, 1919) studied the spontaneous inflammation of mixtures of ether and air. Liquid was passed through a gas-meter and then evaporated in a tube surrounded by a wire coil and sent into a U-tube, the one limb of which was fitted with a series of points. When the amount of ether per litre of air was about 1 gramme, spontaneous inflammation took place at 190 deg. C., in wide tubes probably at lower temperatures, even in the absence of any catalysts such as the oxides of nickel, iron, copper, &c. Near the bluish flame the temperature rose to 460 deg. C. The figures are hardly surprising; it is well known that ether vapours are highly inflammable and that ether, poured on a hot plate, will give rise to a luminous vapour column, though not actually burning with a visible flame. In this latter instance, to which Alilaire does not refer, aldehyde is the most characteristic combustion product, as in ordinary combustion, the other products being acetic acid and carbon dioxide. The new point is that the ignition did not seem to be preceded by any chemical reaction; that statement does not seem to accord with the plate experiment we mentioned, though there would be initial local heatings in that case.

INDUSTRIAL NOTES.

A meeting of the Leeds Chamber of Commerce was held last Tuesday, Sir John McLaren occupying the chair, when Mr. F. Wardle submitted the following resolution :—

"That the Coal Commission at present sitting is not a body fairly qualified to report on the future management of collieries, nor on the question of nationalisation. The question ought not to be settled either in the interests of the miners or owners, but in the national interests, and a Commission appointed to take evidence and report should consists of a majority of coal consumers and traders."

The miners, he said, had threatened to strike if the mines were not nationalised. The men might, he added, have a right to strike on a question of hours and wages, but nationalisation was a wide and economic and political question which had to be settled by Parliament. If the miners wanted nationalisation, they had to get the bulk of the voters to support them. The Government ought peremptorily to tell them that as a trade union they had no standing on the question of nationalisation.

The resolution was adopted unanimously.

The first part of the sitting of the Coal Commission on Wednesday, April 30, was taken up by the cross-examination of Mr. Sidney Webb, an abstract of whose evidence we published on page 566 *ante*.

Sir Leo Chiozza Money then gave evidence and stated that the case for nationalisation was based on the following points: (1) The vital importance of coal in the national economy. (2) The need for the greatest possible conservation of coal. (3) The greater economy of unified control, especially under nationalisation. (4) The superiority of public service as compared with working for private gain, as an incentive in industry. (5) The recognition of the need to associate every person engaged in the industry with the conduct of its economy as far as that was practically possible. The last Coal Commission, Sir Leo added, showed that the collieries were themselves amongst the greatest wasters of coal, and a grave indictment was also brought against the economy of private industry; it was shown that coal consumption per indicated horse-power was about 5 lb.; whereas it should not exceed 2 lb. There was also much waste in the manufacture of coke. The waste of fuel in the iron and steel industry deserved particular attention; in the best modern plant it was not necessary to consume 4 tons of coal to make 1 ton of steel. Referring to the work of the Coal Conservation Committee of 1918, it had been shown that the creation of large central power stations would save 55,000,000 tons of coal per annum, in regard to power purposes alone. No less remarkable than the waste in getting coal and the waste in coal consumption was the national neglect to explore the coalfield. The cumulative effect of these considerations pointed to the urgent necessity of taking national control of power resources. Since the Government, Sir Leo further said, had decided to nationalise the super-power stations, it would seem exceedingly illogical to leave under the private control of about 1,500 different coal owners, not proprietors but lessees, the irreplaceable fuel required for the said power stations. Waste could not be adequately dealt with except under unified control, and the most economical method of unified control was by nationalisation. The further points dealt with by Sir Leo, namely, the formation of a Ministry of Mines, a central mining council, local district councils, &c., appear to us to be similar to those put forward by Mr. Sidney Webb, and referred to in our last issue.

On Friday last, after the cross-examination of Sir Leo Chiozza Money, Mr. Arthur Greenwood, Leeds University, outlined a national scheme, which included a Central Coal Production Council and a Central Coal Consumers' Council. The former, subject to Parliament, would have control of the production of coal, technical and research questions, methods of production, labour conditions. Generally speaking, it would have to secure by the most efficient methods an adequate supply of coal. The other council would have under its jurisdiction all matters common to coal consumers, including transport rates and methods of distribution. A Minister of Mines would be called upon to defend the policy of his department in Parliament. Questions as to the price of coal might be determined by negotiations between the two councils on the basis of published returns on costs. Questions as to the remuneration of the employees would be dealt with by negotiations between the employees' representatives and the Minister. In each district there would be a council established on similar lines as those of the Central Coal Production Council.

Mr. G. H. D. Cole, Oxford University, said we had reached a stage in certain vital industries, including coal mining, if not in industry as a whole, when the workers would no longer consent to remain within the boundaries of the wage system. Nationalisation of the mines was necessary for the sake of the community, in order to secure the fullest utilisation and conservation of a vital natural product in the common interest; for the sake of the consumer, in order to prevent exploitation and profiteering; in order, further, to give to the workers the sense of working for the community and not for the benefit of any private person. Full utilisation and conservation of coal resources could only be secured by modified working, and real unification of working could only be secured by unified ownership. The Whitley Report, he added, might be of a certain amount of use to some of the less organised trades; broadly speaking, however, he did not think it had become of any considerable importance. Profit-sharing schemes also were of very little importance; they did not provide for any real scheme of control and did not give the workers any share in the profits worth talking about.

At the sitting on last Tuesday, it was stated that Sir Adam Nimmo, K.B.E., colliery owner, would now act as a Commissioner in the place of Mr. J. T. Forgie, who had been compelled to retire owing to ill-health.

Mr. L. T. Hobhouse, London University, then gave evidence and stated that as compared with the old system of numerous competitive firms, nationalisation had advantages and drawbacks; intelligently used, the advantages should be the greater. As compared with a mixed system of both public and private control, which appeared to be the only alternative, nationalisation had everything to recommend it. It was probable that any intermediate system would combine the drawbacks and forfeit the advantages of nationalisation and competitive industry.

Mr. J. T. Ryan, Premier and Attorney-General of Queensland, then stated that the present Queensland Government were returned to power in May, 1915, and during their term of office they had largely increased the number of enterprises carried on by the State; previously, the principal lines of railway were controlled by the State under the Railways Act. The additional State enterprises carried on by the present Government included those carried on under Acts of Parliament (mineral oil production, coal mines, iron and steel works, among others), and those carried on under Parliamentary appropriations. These enterprises had been carried on successfully. His opinion was that nationalisation was beneficial to the public generally.

Mr. Westgarth Forster Brown, South Wales, was the next witness. He said that the present system of private ownership of mineral rights had not interfered with the free development of the mineral resources of the country, as was proved by the rapid development which had taken place in the several coalfields of the country. He did not believe that State ownership would lead to any more rapid development of the mineral resources of the country, as his view was that the real factor governing developments was the prospect of obtaining a remunerative return upon the capital to be laid out, and this would vary according to the state of trade. In regard to waste of coal, he referred to the interim report of a sub-committee of the Land Acquisition Committee, and added that it only required some simple procedure of an impartial tribunal to prevent difficulties under this head from occurring. Any difficulty arising between the mineral worker and the surface owner would, he thought, be intensified if the State became the proprietor of the minerals.

Mr. Arthur Lawrence, mining engineer, Cardiff, stated that the average net receipts for royalties of all description received by the lessors for whom he acted in South Wales worked out at 6·29*d.* per statute ton, or only about 2½ per cent. of the cost of production. The average wayleave, where payable, on the estate was 0·86*d.* per statute ton. In many cases free wayleave rights had been granted. He gave several instances in which the lessors had assisted their lessees by the granting of concessions to assist the latter to pass through difficult states of trade. Nationalisation, he also said, was more likely to lead to waste of coal than the present system of private ownership, for the lessee's energies were directed towards realising to the fullest extent all the mineral in his taking; it would, further, inflict a considerable loss of revenue upon the State by reason of the heavy taxation which the present owners were subjected to in the form of mineral rights and increment value duty.

Mr. I. E. Downing, secretary of the Ecclesiastical Commissioners, said the latter were owners of coal and other minerals, especially in Durham and Northumberland. The royalties and wayleaves in respect of coal received in 1917 amounted to 370,000*l.* The parochial clergy were beneficiaries for whom the property was held.

We gave, on page 514 *ante*, information concerning the International Labour Charter. The International Labour Conference appointed for October next will be held in Washington. The organising committee consists of the following members: M. Arthur Fontaine (France) (chairman), Dr. J. T. Shotwell (United States), Sir Malcolm Delevingne (Great Britain), Signor Di Palma Castiglione (Italy), Dr. Oka (Japan), Professor E. Mahaim (Belgium), and Professor W. E. Rappard (Switzerland). Mr. H. B. Butler, Ministry of Labour, will act as secretary. The committee held its first meeting last Tuesday in London. It will meet generally in London; its offices are 53, Parliament-street, S.W. 1.

The agenda for the Washington Conference is as follows: (1) Application of the principle of an 8-hour day, or a 48-hour week. (2) Question of preventing or providing against unemployment. (3) Women's employment: (*a*) Before and after child-birth, including the question of maternity benefits; (*b*) during the night; (*c*) in unhealthy processes. (4) Employment of children: (*a*) Minimum age of employment; (*b*) during the night; (*c*) in unhealthy processes. (5) Extension and application of the International Conventions adopted at Berne in 1906 on the prohibition of the use of white phosphorus in the manufacture of matches.

A meeting of the Provisional Joint Committee of the National Industrial Conference was held in London, on the 1st inst., under the chairmanship of Sir Thomas Munro, chairman of the committee, when Sir Robert Horne, the Minister of Labour, read a letter from the Prime Minister, in which the latter stated that although he could not commit himself to every detail, as many of them were complex and technical, he fully accepted in principle the committee's recommendations as to the fixing of maximum hours and minimum rates of wages. There were certain industries, such as agriculture, in which seasonal and other conditions necessitated special consideration, also some cases, such as those of seamen and domestic servants, in which it would be impossible to enforce a week of 48 hours; he agreed, however, that the Bill now being framed should otherwise apply to all industries in which a legal limitation of hours is practicable. As regarded wages, he accepted the principle that minimum rates of wages should in all industries be made applicable by law. He cordially welcomed the committee's proposal to set up a National Council.

The following resolution was unanimously passed at the meeting: "Having heard the Government's declaration with regard to the proposal of the National Industrial Conference, and in view of the necessity for further joint consideration by the employers' representatives and the trade union representatives, the Joint Committee propose an adjournment in order that both sides may have an opportunity of considering separately, and jointly if necessary, the Government's reply and deciding their attitude thereon; the Joint Committee to meet again on a date to be decided by the chairman."

We read in *The Times* that the Committee on Trusts appointed by the Minister of Reconstruction in February, 1917, to consider what action may be necessary to safeguard the public interest in view of the probable extension of trade organisations and combinations, has completed its sittings and prepared a report for submission to Sir Auckland Geddes.

The committee, it would appear, does not find itself in a position to pass any considered judgment as to the actual existence of abuses tending to the detriment of the public, but measures are suggested which would enable a close watch to be maintained on the growth and activities of trade associations, and give the State power to remedy any grievances arising out of their operations.

Evidence given before the committee appears to have warranted a conclusion that during recent years, and more particularly since 1914, there has been a growing tendency in this country to form trade associations having for their chief purpose the restriction of competition and the control of prices. So far as our contemporary is aware, pending the publication of the report, the evidence failed to show that the formation of combinations had definitely led to excessive charges up to the present.

STANDARDS FOR THE MEASUREMENT OF ELECTRICITY.—The Board of Trade announce that the coils and instruments referred to in the schedule to the Order in Council of January 10, 1910, which approved the several denominations of standards set out in that schedule as denominations of standards for the measurement of electricity will, on and after May 8, 1919, be deposited at the National Physical Laboratory, Teddington, Middlesex, instead of at the Board of Trade, Standardising Laboratory, 8, Richmond-terrace, Whitehall, London. All communications respecting electrical standards and instruments for test should, on and after May 8, 1919, be sent to the Director of the National Physical Laboratory, Teddington, Middlesex.

THE TARRANT TRIPLANE.

ON Monday last we had an opportunity of inspecting the large Tarrant triplane, which is now rapidly approaching completion at the Royal Aircraft Factory, Farnborough. This machine, which, as far as we are aware, is the largest yet in existence, was originally intended for bombing Berlin, and as it is regarded as capable of flying the necessary distance with a load of 16 bombs each weighing 550 lb., our enemies must congratulate themselves that it was not completed before the termination of hostilities.

Before commencing a detailed description of the machine it will be as well to mention some of the main dimensions in order to give an idea of its immense proportions. Its overall length is 73 ft. 3 in., and the total height from the ground to the upper surface of the top plane is 37 ft. 3 in. The middle plane, which is the largest of the three, has a span of 131 ft. 3 in., and the top and bottom planes are each 98 ft. 5 in. in length. The chord of all three planes is 15 ft. 2 in., giving a total wing area of 4,950 sq. ft., and since the weight of the machine, fully loaded, is 45,000 lb. (20 tons) the wing loading works out at just over 9 lb. per square foot. The gaps between the planes are slightly less than the chord length, the actual figure being 14 ft. 9 in. The power plant consists of six Napier "Lion" engines, each of 500 h.p., and, when running "all out," these are expected to give the fully-loaded machine a speed of over 110 m.p.h. Two engines, driving respectively a "pusher" and a "tractor" screw, are mounted in tandem midway between the middle and bottom planes, and a single engine driving a "tractor" screw is mounted vertically above them between the middle and upper planes. The "tractor" screws are all two-bladed, and are 12 ft. 6 in. in diameter, whilst the "pusher" screws, which are four-bladed, are 10 ft. 7½ in. in diameter. A similar group of three engines is, of course, mounted on both sides of the fuselage, the horizontal distance between the centre lines of the two groups being 34 ft. 5 in.

The chief interest in the machine, however, centres more around the special form of timber construction used for several of the more important members, rather than in its dimensions. We can most conveniently describe this construction, which was patented by Mr. W. G. Tarrant, of Byfleet, in connection with the spars of the main planes, although the application of the system to the construction of the fuselage is really of greater interest. Fig. 1 is a section of the front spar of the central portion of the top plane, and Fig. 2, which is a side elevation in perspective of the same spar, also shows the method of attaching a rib. It will be seen that each spar consists of a lattice girder, or rather a pair of Warren girders, the flanges of which are made up of three vertical laminations. Grooves are formed on the inner vertical faces of the laminations, and the cross-bracing members are formed with beads which fit into the grooves as shown in the illustrations. Beaded strips are fitted into the longitudinal spaces between the ends of the cross-members to act as distance pieces, so that, when glued up, the whole flange is quite solid. It will be obvious that this method of construction, which is also used for the tail-plane spars, fuselage, bomb racks, &c., enables short lengths of timber to be used, and also practically eliminates the risk of internal defects passing unnoticed. The timber used for the main-plane spars is American whitewood, except in the case of the rear spar of the top plane, in which both pine and whitewood are employed. It is claimed that the spars are about 10 per cent. lighter than corresponding box sections would be, on the reasonable assumption that the sides of the latter could not be made less than ⅛ in. in thickness for practical reasons.

Fig. 1 FRONT SPAR

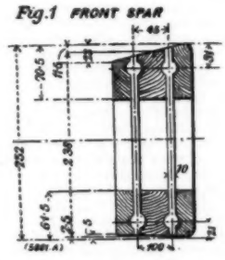
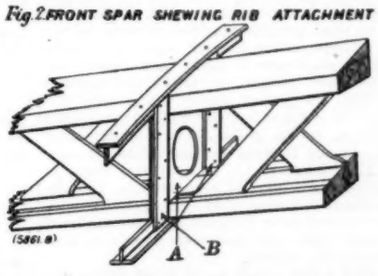


Fig. 2 FRONT SPAR SHEWING RIB ATTACHMENT



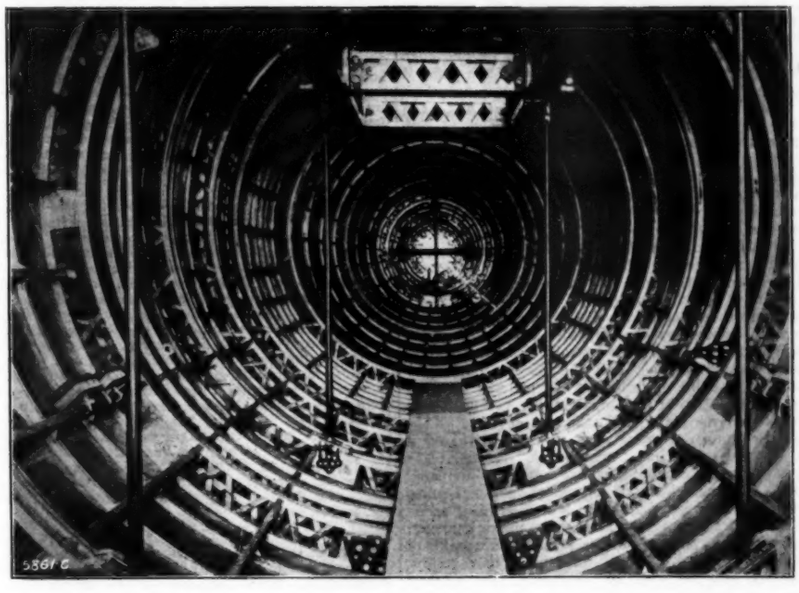


FIG. 3.

The fuselage is a stream-line body of circular section and of monocoque construction, having a maximum diameter of 11 ft. and a length only slightly less than that of the overall length of the machine, which is 73 ft. 3 in. It is attached to the wings between the middle and bottom planes. The body is built up of a series of main rings constructed on the same principle as that described above in connection with the wing spars, and between these main rings are a number of lighter single rings, or formers. Longitudinal members, or longerons, run from the nose to the tail, and the construction is such that neither the rings nor the longerons are cut at the points of intersection. In the cylindrical part of the body the longerons are constructed similarly to the spars, but from this part the inner flange tapers down and forms a single member which extends to the end of the body. The whole body is covered with two-ply wood applied in strips 1½ in. wide, and arranged so that the strips forming the two layers are approximately at right angles. A further covering of fabric, varnished and enamelled to render the whole structure weatherproof, is also applied. The photograph reproduced in Fig. 3 shows the internal appearance of the body, which is certainly a very remarkable piece of joinery work. The horizontal girder seen in the upper part of the illustration is a part of the bomb rack. The weight of the whole fuselage, including that of the bomb girders, is given as 3,950 lb.

The pilot's cockpit is situated in the upper part of the fuselage near the nose, and, as two pilots are intended to sit side by side, the controls are in duplicate. Behind this is a cabin in which the engine starting and controlling levers are mounted on a partition which forms the forward end. An engineer will be carried in this cabin and his duties will be to start the engines, watch the petrol supply and cooling arrangements, and generally attend to their working, thus relieving the pilots of a considerable part of their normal work. The throttles are under the control of the pilots, and a master switch fitted in the cockpit enables the engines to be cut out at the right moment in landing, or in case of emergency. The main petrol supply is stored in tanks fitted on the top and sides of the body to the rear of the engineer's compartment, the centre part being left clear for carrying the bombs. The tanks have a capacity of 1,600 gallons of petrol, which is sufficient to supply the engines, all running at full power, for 8 hours. The distance travelled in this way would be about 900 miles, but by cutting out two of the engines, and throttling down the others, it is estimated that a maximum distance of 1,200 miles could be covered. The maximum height attainable, or the "ceiling" as it is usually called, has been calculated as 13,000 ft., and the time required to reach this height should be just over an hour; a height of 10,000 ft. would, however, be reached in 33½ minutes. Of the total weight of the machine given above as 45,000 lb., 19,000 lb. may be taken as the useful load. Petrol accounts for 10,000 lb. of this, leaving 9,000 lb. available for bombs, or for passengers and cargo, if the machine were used for commercial purposes.

Some further particulars of the main planes may be of interest in addition to the general dimensions previously given. The section used is R.A.F. 15, and the wings are set at an angle of incidence of 3 deg. with the longitudinal axis of the fuselage. There is no "stagger," and the central parts of the wings between the engine bays are horizontal in front elevation, the outer parts, however, have a dihedral angle of 4 deg. on each wing. Ailerons are fitted on the middle plane only, and are each 105 sq. ft. in area, which seems rather small in comparison with the wing area. They are balanced by being hinged on a line 9 in. to the rear of the leading edge.

The tail unit is of the biplane type with balanced elevators hinged to each plane and an intermediate elevator, also balanced, fitted midway between the planes vertically under the upper elevator. This inter-elevator is connected by stream-line struts to the lower elevator, and the two are used together for the longitudinal control of the machine. The upper elevator, which is independent of the other two, can be adjusted by the pilot for altering the trim of the machine. The extreme width of the elevators is 30 ft., and the distance from the leading edge of the tail plane to the trailing edge of the elevator is 9 ft. 6 in. The gap between the planes is 10 ft. The area of the tail planes is 184 sq. ft. each, and of the main elevators 81 sq. ft. each; the inter-elevator is 54 sq. ft. in area. The upper tail plane is set at a fixed angle of 2 deg. with the axis of the fuselage, and the lower plane, which is nominally set at 0 deg. incidence, can be adjusted slightly on the ground. The interplane struts of the tail plane are used to carry the two vertical fins, behind each of which is mounted a balanced rudder. The area of each fin is 42 sq. ft., and of each rudder 31 sq. ft. A rather novel form of tail skid, described as Barling's patent, is used on the machine. The arrangement consists of four struts projecting downwards from the rear end of the fuselage and carrying a fitting having vertical slots in which a cross-bar attached to a large shoe can slide. The shoe is guided by a radius rod hinged to the fuselage some distance in front of the four struts, and is attached to the fixed fitting by several loops of braided rubber cord which tend to prevent the shoe from moving upwards and absorb the shocks by their extension. The only other detail we have space to deal with here is the landing chassis of which there are two, one being placed under each of the engine bays. Each chassis has three wheels, fitted with Palmer cord tyres, the dimensions of which are 1,500 mm. by 300 mm. The wheels are mounted closely side by side on an axle which is carried at the centre of two horizontal beams. These beams are bound by a large number of turns of rubber cord to the

upper sides of two similar beams, which form the lower members of the chassis structure, and are connected by struts at their front and rear end to the interplane struts of the main planes. The front and rear panels of the structure so formed are strongly braced to resist side loads.

The woodwork for the machine has been constructed at Mr. Tarrant's works at Byfleet, and the erection has been carried out at the Royal Aircraft Factory, where the metal parts have also been made. The construction of the machines has occupied a very long period, and the original design has been considerably modified by Captain T. M. Wilson. The machine is expected to make its trial flight within the next few weeks, and the results of the test will be awaited with considerable interest. A fairly extended period of service will, however, be required to prove that the special form of timber construction adopted is satisfactory in every way. To us it appears to be hardly suitable for use in a hot, humid climate, though it must be admitted that the more usual construction also suffers from this disability. For a commercial machine, travelling long distances under widely varying climatic conditions, some form of metal construction would appear to be better from the point of view of durability, and it would have the additional advantage of being more nearly fireproof. The Tarrant fuselage construction, however, has one distinct advantage for commercial work in that the usual struts and bracing wires are absent, and the greater part of the interior can thus easily be arranged for passenger accommodation or for the stowage of cargo. A second machine, exactly similar to that above described, is also under construction for the Government.

VICKERS' VIMY-ROLLS AEROPLANE.

WE reproduce on page 606 two photographs of the aeroplane which Messrs. Vickers, Ltd. (Aviation Department) have entered for the Transatlantic Flight, for which a prize of £10,000 has been offered by the *Daily Mail*. In all essential details the machine is similar to the firm's well-known "Vimy" bomber, a number of which were supplied to the Government for war work, but certain modifications have, of course, been made in the equipment in order to render it capable of completing the journey across the Atlantic.

The main object in designing the Vimy bomber was to produce a machine capable of carrying a useful load of some 5,000 lb., but of smaller dimensions, and more easily handled, than existing machines of equal capacity. The comparatively small dimensions, and the excellent performance of the machine, show that the original object has been satisfactorily attained. The overall length of the machine is 42 ft. 8 in., and the total height is 15 ft. 3 in. The span of the main planes, both of which are equal, is 67 ft., and the chord is 10 ft. 6 in. This gives a wing area, allowing for the part of the bottom plane cut away for the fuselage, of 1,330 sq. ft. Equipped for military work, with a crew of three men, a bomb load of 1,146 lb., 470 gallons of petrol, and a sufficient quantity of oil, water, guns, ammunition, &c., the total weight of this machine is 12,500 lb., so that the wing loading is 9·4 lb. per square foot. With this loading a fairly low landing speed is possible, and this, we understand, is 45 m.p.h. The machine illustrated is equipped with two Rolls-Royce "Eagle" engines, each of 350 h.p., and each driving a four-bladed "tractor" screw 10 ft. 5 in. in diameter at 1,080 r.p.m. As will be seen each engine is enclosed in a casing, of approximately streamline form, carried between the main planes by four steel tubular struts of circular section fitted with wooden fairings. The design of these casings is interesting in that the proportions were determined by experiments in the firm's private wind tunnel as those giving the minimum air resistance for a body having a flat front face. The flat front in this case is formed by the radiator, which, as will be seen, is fitted with louvres to enable the temperature of the cooling water to be regulated. The engines give the machine a speed of 100 m.p.h. when fully loaded with bombs at a height of 10,000 ft., which height is reached in 50 min. Without bombs the same altitude is reached in 23 min., and the speed in this condition is 103 m.p.h. The machine is capable of flying for 11 hours at full speed at a height of 10,000 ft.

To the overall dimensions of the main planes already given we may add that the gap between them is 10 ft. The planes are horizontal between the engine bays, but the outer parts of both wings have a dihedral angle of 3 deg.; they are set to an angle of incidence of 3½ deg. with the axis of the fuselage. The spars are of box section built up of spruce and ply wood, and bound with fabric, and the interplane struts, except those carrying the engines, are of hollow spruce. The machine is inherently stable under all conditions, and is fitted with a compensating device which enables it to be flown without touching the control lever, whether flying level, climbing or gliding. For lateral control comparatively large balanced ailerons are fitted on both main planes. These ailerons are each 59·5 sq. ft. in area, but the balance is such that very little effort on the part of the pilot is required to move them. The ailerons, and all other control surfaces, are operated in the usual manner by wire cable.

The front portion of the fuselage, as far as the rear spars of the main planes, is constructed of steel tubes, and to the rear of this point a special wooden tube is used for the longerons under Vickers-Ryan patents. The fuselage is braced with swaged steel tie rods. In the nose of the fuselage is the bomber's cockpit, in which the bomb sights and bomb releasing gear are situated; it is also fitted with a Scarffe mounting for a Lewis gun. The bomber, however, usually sits beside the pilot in a second cockpit immediately behind the front cockpit, and only enters the latter when ready to drop the bombs. There is a third cockpit in the fuselage just behind the trailing edge of the main planes to accommodate a gunner. This cockpit is provided with a Scarffe mounting, and is also arranged so that the gunner is able to fire through the bottom of the fuselage in a horizontal direction towards the rear. He can thus aim at a machine following at the same level without hitting the tail plane of his own machine. The main petrol tanks and bombs are carried in the space between the pilot's and gunner's cockpits. From the petrol tanks, which hold 470 gallons, the petrol is raised by centrifugal pumps, driven by air screws, to service tanks situated in the upper main plane, whence it flows by gravity to the carburettors. The delivery to the service tanks is, however, always in excess of requirements, and the overflow returns to the main tanks. The petrol pumps, it may be mentioned, were designed and manufactured by the Vickers firm, and have been largely used on almost all makes of machines.

The tail plane, which is well shown in our illustration Fig. 1, is a biplane structure, the planes of which are set at an angle of about 2½ deg. with the fuselage axis. The planes have a span of 16 ft., and the distance from the leading edge of the tail plane to the trailing edge of the elevator is 6 ft. 2½ in. The area of each plane is 77 sq. ft., and the elevators, which are not balanced, are 16 sq. ft. in area. Two "K" shaped fins, each 14 sq. ft. in area are sometimes provided to give additional directional stability, and it will be noticed that these have been fitted to the Transatlantic machine. Behind these fins are two balanced rudders having an area of 9 sq. ft. each. Two "V" type landing chassis are provided, one under each of the engine bays as is best shown in Fig. 2, and each chassis has two wheels fitted with Palmer cord tyres, the dimensions of which are 900 mm. by 200 mm. A bentwood skid is fitted to the nose of the fuselage to diminish the effects of a bad landing.

To equip the machine for the Atlantic flight it was, of course, necessary to provide greatly increased capacity for the storage of petrol. The bomb racks were therefore removed, and the space occupied by these, and also by the gunner's cockpit, was used for the accommodation of the extra tanks. As will be seen from the engraving, Fig. 1, the part of the fuselage where the gunner's cockpit was previously situated is now covered by a neat "turtle-back" fairing. The capacity of the petrol tanks has now been increased to 865 gallons, which, it is calculated, will give the machine a range of 2,440 miles at a cruising speed of about 90 m.p.h. The maximum speed, however, is still over 100 m.p.h., and the machine is capable of flying at about 70 m.p.h., with one engine out of action. It should thus be able to complete the journey unless both engines fail. The bentwood front landing skid, above referred to, was replaced by a wheel carried by an auxiliary "V" type chassis, and clearly shown in Fig. 2, but this, we understand, has now been removed, as preliminary trials have apparently convinced the pilot, Captain J. Alcock, D.S.C., that it was unnecessary. A powerful set of wireless apparatus, with a range of 250 miles, has been installed for communication purposes, but we understand that this will not be used for navigation. For this purpose the navigator, Lieutenant Arthur W. Brown, A.M.I.E.E., M.I.M.E., will use methods similar to those employed in ordinary marine navigation. No arrangements have been made for salving the machine in the event of a forced "landing" at sea, but the pilot and navigator will wear Gieve life saving jackets. One of the petrol tanks, which has been made quickly detachable, has a buoyancy of 600 lb., and this will also be utilised to keep the men afloat until picked up by a passing vessel. The machine, which was taken ex-contract from a batch constructed at the Weybridge works of the company, has completely satisfied the pilot and navigator in the preliminary trials at Brooklands. It has now been dismantled and packed for shipment to Newfoundland, as the flight will be made in an easterly direction. Mr. R. K. Pierson was responsible for the design of the machine. In conclusion we may add that the Vickers "Vimy" bomber has been fitted with several engines other than the Rolls Royce, among them being the 300 h.p. Fiat, the 375 h.p. Lorraine, the 260 h.p. Salmson, and the 400 h.p. Liberty. The performance, of course, varies considerably according to the properties of the engine.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—As was forecasted, the removal of Government subsidies resulted in an advance in iron prices of from 45*s.* to 50*s.* per ton. To-day's quotations (delivered in Sheffield) are West Coast hematites, 185*s.* 6*d.*; East Coast hematites, 178*s.* 9*d.*; Derbyshire foundry, 146*s.*; Derbyshire forge, 144*s.*; bars, 22*l.*; sheets, 25*l.* Makers state that these quotations apply only to the ensuing month, and hint that further advances are not unlikely to cover the increased cost of production at the end of that period. Opinions as to the effect of enhanced basic prices on the steel trade generally, and particularly on export trade, are divergent, but those emanating from the most responsible quarters are not too hopeful. Already, as a result of these advances, the productive cost of ordinary brands of steel has advanced 4*l.* to 5*l.* per ton. In view of the decline in American rates, manufacturers report considerable difficulty in satisfying export buyers, and apparently only a small proportion of contracts for Continental reconstruction work are falling to the lot of British manufacturers. It is also feared that the enhanced prices of steel will have a hampering effect on the constructional trade, and that building costs will further advance. It is reported that Lorraine and Luxemburg are offering steel to British makers at prices well below British quotations, but there is no evidence of orders having been booked with the French market. Trade in crucible steel is flat, and there is very little sign of improvement in the high-speed steel trade. Works still have on hand considerable stocks left over from war manufacture, and, until these are cleared, the prospect of an improvement is not very promising. Values of steel alloys continue to decline, but there are few buyers. Tungsten is now quoted at 3*s.* to 3*s.* 6*d.* a pound. Shipbuilding requirements are not large, but activity in railway stock construction, both at home and abroad, is responsible for a satisfactory influx of orders. Axles, tyres, tubes and springs are an improving market, despite keen competition, some of it from German firms. Locomotive tube makers are very well booked forward. Business in the tool trades, and in files, saws and gardening requisites, is developing into boom proportions. Several of the representative firms are booked for six months ahead, and in some cases where output cannot be further increased by the introduction of labour-saving devices or up-to-date machinery, orders are being turned away.

South Yorkshire Coal Trade.—There is little or nothing on offer on the open market, outputs practically being absorbed to meet contract requirements on home and export account. The demands of railway companies, blast furnaces and home manufacturing concerns keep the hard coal pits fully occupied. Cobbles, nuts and slacks are all in strong call for bunkering, and other home requirements, and collieries find difficulty in fulfilling demands. A general complaint of shortage characterises the house coal section. In this respect the pits have not yet fully recovered from the holiday stoppage. A general difficulty in obtaining supplies is also reported respecting coke, which continues a firm market at maximum rates. Quotations:—Best branch handpicked, 27*s.* to 28*s.*; Barnsley best Silkstone, 27*s.* to 27*s.* 6*d.*; Derbyshire best brights, 25*s.* to 26*s.*; Derbyshire house coal, 22*s.* 6*d.* to 23*s.* 6*d.*; best large nuts, 22*s.* 6*d.* to 23*s.* 6*d.*; small nuts, 21*s.* 6*d.* to 22*s.* 6*d.*; Yorkshire hards, 22*s.* 6*d* to 23*s.* 6*d.*; Derbyshire hards, 21*s.* 9*d.* to 22*s.* 9*d.*; best slacks, 18*s.* to 19*s.* 6*d.*; seconds, 16*s.* to 18*s.*; smalls, 13*s.* to 14*s.*

BRITISH INDUSTRIES FAIR, BIRMINGHAM.—We are informed that a British Industries Fair will be held in Birmingham, from February 23 to March 5, 1920, concurrently with the British Industries Fair, London and Glasgow, and under the auspices and support of the Board of Trade and the joint organisation of the Birmingham Municipality and Chamber of Commerce. The patron is the Right Hon. Sir Albert Stanley, President of the Board of Trade, and the president the Right Hon. the Lord Mayor of Birmingham. The offices are, Chamber of Commerce, 95, New-street, Birmingham.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—This Institution will hold a summer meeting in Newcastle, from July 9 to 11. The object of the meeting is to set on record the share contributed by the engineering and shipbuilding industries of the North-East Coast of England towards the successful prosecution and victorious culmination of the war. Copies of the papers will be available in June. The list of papers is the following: "Women's Work in Engineering and Shipbuilding during the War," by the Hon. Lady Parsons; "Shipbuilding and Marine Engineering Done on the North-East Coast during the War," by the president, Mr. Edwin L. Orde; "Aviation During the War, and its Possible Future," by Lord Weir; Lecture by Professor McLennan; "Dazzling of Ships," by Lieutenant-Commander Wilkinson; "Limits of Thermal Efficiency in Diesel and Other Internal-Combustion Engines," by Sir Dugald Clerk; "Ship-repairing During the War," by Mr. M. C. James and Mr. Launcelot E. Smith; "Transmission of Power," by Mr. G. Constantinesco. The secretary, Mr. E. Fraser Smith, Bolbec Hall, Newcastle-on-Tyne, will be pleased to answer any inquiry concerning the meeting.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Buyers of Cleveland pig-iron are very keen to place orders, and values are advancing rather rapidly. There is, however, but little available for sale, many makers in fact having sold their output to the end of June, and beyond that date they refuse to commit themselves, so that efforts of buyers to make contracts over the third quarter of the year have, so far, been unsuccessful. Furnaces are still working unsatisfactorily, with the result that they are producing a greater proportion of forge iron than foundry quality, and the latter is the description in heaviest demand. Eager inquiry from abroad is reported, and with freights falling, and tonnage plentiful, foreign trade is limited only by the scarcity of iron. It is rather difficult definitely to fix quotations, but 147*s.* 6*d.* may now be given as round about the market rate for No. 3 g.m.b. Cleveland pig-iron, No. 4 foundry and No. 4 forge, whilst No. 1 is put at 151*s.* 6*d.* Buyers are quite prepared to pay these prices, and in odd cases higher rates have been paid.

Hematite Iron.—East Coast hematite producers are in a very strong position, being so well sold that they hesitate to entertain new business. Output is being railed straight from the pig-iron beds. Nothing under 180*s.* is now named for Nos. 1, 2 and 3, and No. 1 commands at least 182*s.* 6*d.*

Manufactured Iron and Steel.—Home demand for several descriptions of finished iron and steel shows some falling off, but shipbuilding requisites and railway material continue in good request. Inquiries from abroad keep on a pretty good scale, and shipments to the Far East are rather large. In the export trade prices vary, but are generally somewhat above the following minimum figures, which govern home sales:—Common iron bars, 20*l.* 10*s.*; marked bars, 23*l.*; strip iron, 21*l.* 15*s.*; steel strip, bridge and tank plates, 17*l.*; steel angles, 16*l.* 10*s.*; steel joists, 16*l.* 10*s.*; steel hoops, 23*l.* 5*s.*; and heavy sections of steel rails, 15*l.* Buyers are stated to be offering 18*l.* for steel plates for shipment abroad.

Shipments of Iron and Steel.—Official April returns show the shipments of iron and steel from the port of Middlesbrough to be the heaviest of any month so far this year, the total clearances amounting to 51,472 tons, of which 22,773 tons were pig-iron, 1,424 tons manufactured iron, and 27,275 tons steel. Of the pig-iron shipped 15,397 tons went to foreign ports, and 7,376 tons coastwise; of the manufactured iron loaded 1,305 tons went abroad, and 119 tons coastwise; and of the steel cleared 22,866 tons went foreign, and 4,409 tons coastwise. The largest receivers of pig-iron were Belgium, 5,283 tons; Scotland, 4,893 tons; Italy, 4,397 tons; France, 2,570 tons; the United States of America, 1,766 tons; and the heaviest importers of steel were: The Straits, 5,017 tons; India, 3,429 tons; China, 3,087 tons; France, 2,829 tons; New Zealand, 1,921 tons; and the Cape, 1,124 tons.

Foreign Ore.—Indications of considerable expansion of business in foreign ore are not wanting. Consumers are at last coming into the market. Quotations may be based on round about 45*s.* c.i.f. Tees for rubio of 50 per cent. quality. Freights are easier.

Coke.—There is a very plentiful supply of coke. Average blast-furnace quality is 39*s.* at the ovens, and low phosphorus sort 41*s.* 6*d.* at the ovens.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—Again during the past week business has been retarded by holiday-making on the part of the miners, for on Monday they were idle in connection with their annual Demonstration Day, which had been suspended during the war. With coals already scarce, the shortage was further increased by a loss of another day's output, for on Tuesday, only about 75 per cent. of the men returned to work. On top of this another strike has broken out at Ebbw Vale, where 5,000 miners are idle, and also the whole of the steel works, which affects another 5,000 men. In these circumstances, large and small steam coals of all classes remained in short supply, and with the demand for home consumption and from the Allies as brisk as ever, buyers find it very difficult to obtain their requirements. Lately there has been a substantial reduction in the arrival of shipping and detention is not now so acute as it had been, though vessels which are to load cargoes for neutral countries are still detained as the Allies get the preference. Taken all round, the trimmers' new working hours are working fairly well, though complaints are heard of boats taking longer to load than was previously the case owing to the breaks between shifts. It is not unlikely that 'ere long there will be a shortage of tonnage, for lately offers of steamers on the freight market have been considerably below requirements, while the restrictions in regard to the chartering of vessels for Spain are not inducive to an active business, and merchants are almost confined to Spanish tonnage. At a meeting of the Cardiff Committee for the supply of coals to France and Italy, yesterday, the question was considered as to whether the scheme should be modified to allow merchants who were not shippers before the scheme came into force to participate in French, Belgian and Italian business providing they could obtain authorisations. It is understood that in the North the view is gaining ground that exporters who were not pre-war shippers should be allowed to send coals to France and Belgium, and that the time has now come when the existing regulations should be modified. The meeting, after having considered the matter, decided to oppose any alteration in the present scheme, and the view was expressed that it is not unlikely that the schemes now in force will be abandoned during the next few months.

Newport.—The stoppage of work at the Ebbw Vale pits of 5,000 men, and the consequent loss in output has further accentuated the shortage of Monmouthshire coals. A heavy demand still exists on inland and allied account, while there is also an active inquiry from neutrals. Inland and allied business receives preference from the authorities, and consequently neutral business remains restricted, and buyers can only obtain small isolated parcels. There is sufficient tonnage in dock to meet exporters' current requirements, though there is a possibility of a shortage in this respect in the near future. Collieries generally are fully stemmed over the next couple of weeks, and, provided expected tonnage turns up to time, there is not likely to be any easement in the existing pressure for coal in the immediate future.

Another Strike at Ebbw Vale.—The miners at the Ebbw Vale collieries have again come out on strike, with the result that the steelworks are also idle and about 10,000 men are involved. The strike has some features of an exceptionally interesting character, inasmuch as it has been engineered by a few local extremists, and is not approved by the leaders. As a matter of fact, when the owners' side of the Joint Dispute Board, at a meeting held yesterday, called attention to the matter, the workmen's representatives, after considering the question in private, declined to take up the case of the men. It seems obvious that the trouble has been brought about by a few malcontents and that the men have no real grievance.

Miners and Colliery Officials.—An important step was taken at the last meeting of the South Wales Miners' Federation in regard to the attitude adopted by the federation towards colliery officials. A deputation attended from the South Wales Colliery Officials' Union and submitted terms for affiliation with the federation. The council approved of these terms, with the result that for the first time in the history of the coalfield there will be an understanding between the miners and the officials, as to any action which might be taken by either of the two organisations indicated. It may be explained that the Officials' Union consists of the lower-grade members of the colliery staffs, ranging from the under-manager downwards. At the same meeting the Federation Council declined to enter into any arrangement with the National Union of Clerks on the ground that they could not support craft unions, in connection with the collieries.

South Wales Colliery Managers and Control of Mines.—At the annual meeting of the South Wales branch of the Colliery Managers' Association, held at Cardiff this week, an interesting discussion took place regarding the position of managers, and a very strong stand was taken on the point that whatever happens as a result of the present Commission of Inquiry, there cannot be any dual control at collieries. The colliery manager, it was emphasised, must at all costs retain inviolate the principle that the management of the colliery must be vested solely in the colliery manager, who is responsible for both the safety and the working of the mine. In order to protect their interests and to make their position more secure the managers decided to convert their organisation into a modified form of trade union, so that in future the association will deal with matters affecting conditions of employment as well as with technical aspects of the profession.

Cardiff Coal Trimmers and Pooling Scheme.—It is expected that a scheme for pooling wages and for dispensing with the services of coal foremen will be brought into operation at Cardiff, Penarth and Barry, the same as has been recently done at Newport and Swansea. The Cardiff trimmers at a meeting this week, after a ballot, decided to pool their weekly earnings, and also to split themselves into 16 sections and to appoint 16 supervisors to be elected from their number. It was also proposed that coal foremen should not in future be allowed a share in the men's earnings. The decision of the men is not final, for a ballot of the whole of the members is to be taken on the question, which will then come before the Central Trimming Board for the formulation of a joint scheme. The Bristol Channel trimmers have also put in for an increase of 20 per cent. on the war bonus, and at a meeting of the Trimming Board held yesterday the employers rejected the claim on the ground that the present state of trade did not justify a further advance.

CONTROL OF BRITISH DRY DOCKS.—The Ministry of Shipping state, with reference to their letter of January 9 last, concerning the control of dry docks, that it has now been found possible to relinquish the control on May 31, from which date shipowners will be free to make their own arrangements, power, however, being reserved to order priority for Government requirements, where considered necessary.

THE LATE MR. JOSEPH JOHN LEE.—We regret to have to announce the death, which occurred on April 23, at "Kirklees," Bushey, Herts., of Mr. Joseph John Lee, of the London and North-Western Railway. Mr. Lee became a member of the Institution of Civil Engineers in February, 1885. He served a pupilage of five years under the late Mr. Hedworth Lee, engineer of the Chester and Holyhead Railway from 1866 to 1871, and in April, 1872, was appointed district engineer on the Tasmanian Main Line Railway, under Messrs. Edwin Clark, Punchard and Co. In 1875, he returned to England. Mr. Lee was in his sixty-eighth year.

NOTICES OF MEETINGS.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, May 9, at 7.30 p.m., at 39, Victoria-street, Westminster, S.W. "Pneumatic Tyres as Applied to Road Vehicles and their Automatic Inflation," by Mr. R. Barnfather, Junr. Friday, May 16, at 7.30 p.m., "Notched-Bar Tests," by Major H. P. Philpot, R.A.F.

THE PHYSICAL SOCIETY OF LONDON.—Friday, May 9, at 5 p.m., at the Imperial College of Science, Imperial Institute-road, South Kensington, S.W. Agenda: (1) Demonstration of a New Method of Producing Coloured Designs upon Glass, by Mr. A. E. Bawtree, F.R.P.S.; (2) "Absolute Scales of Pressure and Temperature," by Mr. F. J. Whipple, M.A.; (3) "On the Transmission of Speech by Light," by Mr. A. O. Rankine, D.Sc.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Wednesday, May 14, at 6 p.m., at the Institution of Civil Engineers, Great George-street, Westminster, S.W., "Wireless in the Royal Air Force," by Major J. Erskine-Murray, R.A.F., Member. Thursday, May 15, at 6 p.m. (light refreshments at 5.30 p.m.), "The Telephone Service of Large Cities with Special Reference to London," by Mr. E. A. Laidlaw, Member, and Mr. W. H. Grinsted, Associate Member.

THE CERAMIC SOCIETY.—Monday, May 12, at 7.30 p.m., in the Central Schools of Science and Technology, Stoke-on-Trent. Business: President's Address, Council's Annual Report, and election of officers.

THE ROYAL SOCIETY OF ARTS.—Wednesday, May 14, at 4.30 p.m., Ordinary Meeting: "Railway Transport in the United Kingdom," by Mr. H. Kelway-Bamber, M.V.O., M.Inst.Loco.E., late Superintendent of Rolling-Stock, East Indian Railway. Major-General Sir Philip Nash, K.C.M.G., C.B., will preside. Thursday, May 15, at 4.30 p.m., Indian Section: "Soil Deficiencies in India, with Special Reference to Indigo," by Professor H. E. Armstrong, Ph.D., LL.D., D.Sc., F.R.S. Sir William Duke, G.C.I.E., K.C.S.I., will preside.

THE SWEDISH STATE RAILWAYS DURING THE WAR.—The Continental railways have, on the whole, fared badly during the war, more especially during the last year or two; and the Swedish State railways, which under normal conditions yield a substantial surplus, have a deficit for 1918 of 60,300,000 kronor. Receipts and expenditure during the last three years are as under:—

	Receipts. Kr.	Expenditure. Kr.	Results. Kr.	
1916	150,170,000	125,550,000	24,620,000	(surplus).
1917	162,440,000	155,180,000	7,260,000	(surplus).
1918	255,420,000	315,720,000	60,300,000	(deficit).

It is more especially the question of fuel which has tended to swell the expenditure, and the increased pay to the *personnel*. Altogether the expenditure during 1918 shows an increase of 103·5 per cent. on that of the preceding year, whilst the receipts have only increased 57·1 per cent., compared with the previous year. The increase in the receipts is due to the material rise in rates which came into force during the year, but as will be seen from the above they were not adequate, nor could they be expected to be so. In addition, the increase in the pay of the officials and men served to swell the expenditure very seriously. Several branches of the transport had to be carried out at prices far below the increased rates. For instance, the transport of the Lapland iron ore had mainly to be undertaken under the rates fixed in the agreement of 1907, which fact alone means a difference of 32,000,000 kronor. The military and mail service has also been run at rates which are not in accordance with the increased expenditure, the result being a loss to the State railways of respectively 1,500,000 kronor and 4,500,000 kronor. [18 kronor = 1*l.*]

IMPORT RESTRICTIONS WITHDRAWN.—The restrictions on importation of the following goods are to be removed:—Hand cultivators; hand drills; seeders; seed-cleaning machines; horseshoes; potato diggers; potato planters; furrows and root weeders; pea harvesters; manure scoops; hay rakes; corn planters; malleable tube fittings; pressure regulators, lubricators, grease cups, injectors and ejectors, pump and engine governors, pressure and vacuum gauges; expansion joints, iron or brass; pressed steel union couplings; water-gauge fittings; steam traps; metallic steam packing; brass wire, copper wire, copper-clad wire, phosphor wire, coppered steel spring wire, tinned mattress wire, wire, leading in nickelled copper, steel wire coppered and flattened; wire rope sockets, drop-forged steel; copper rods and steel and iron wire rods; antimony, crude, regulus and sulphide; Ampoule files; lead capsules for whisky and other bottles; gas irons; cattle de-horning instruments; mathematical instruments and screws for same; oil cans; spectacle cases of metal; hand stamps for numbering and dating, and stapling presses; tinned iron spoons and forks; rat and mouse traps, wood with wire springs, &c.; electrotypes, zinc plates for manufacture of printing plates and zincos, also copper plates and brass plates. No further licences are to be issued beyond those which have been recommended by the Agricultural Machinery Department for: binders, cultivators (horse), cultivators (tractor), sprayers, drills, hay loaders, harrows (potato), harrows (disc), harrows (spring), mowers, ploughs (horse), reapers, reaping attachments, silo fillers, tedders, tractor hitches, trussers. The importation of gun-metal, brass or bronze valves for gas, water and steam, is to be restricted to 100 per cent. of 1916 imports.

VICKERS' VIMY-ROLLS AEROPLANE FOR TRANSATLANTIC FLIGHT.

CONSTRUCTED BY MESSRS. VICKERS, LIMITED, LONDON.

(*For Description, see Page* 604.)

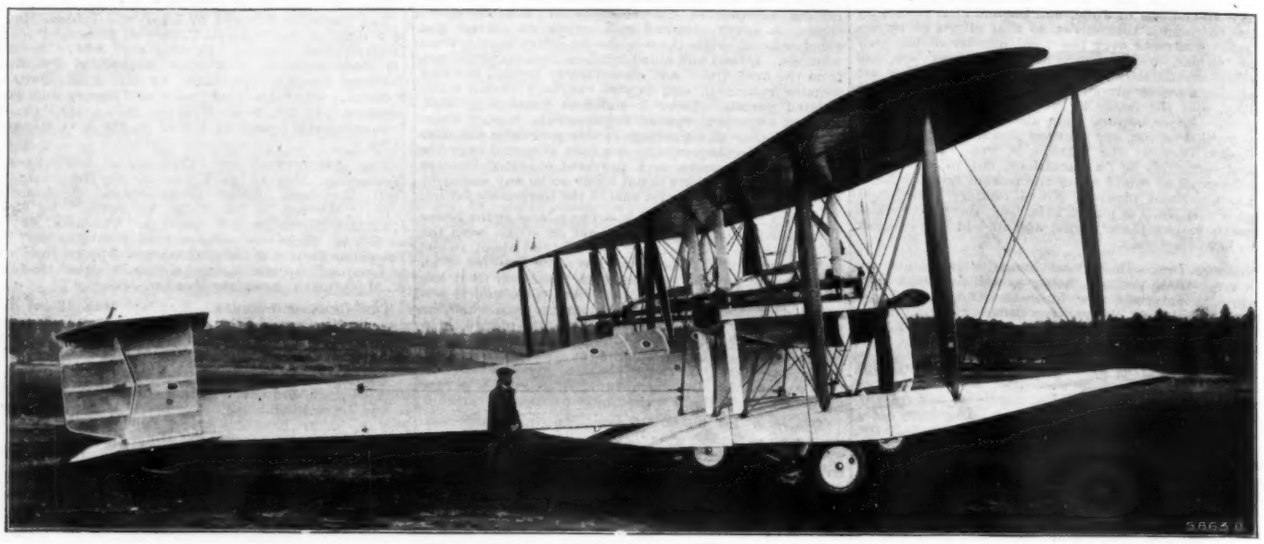


Fig. 1.

Fig. 2.

NOTES FROM THE NORTH.

Glasgow, Wednesday.

Scotch Steel Trade.—Steel makers in the West of Scotland have no need to complain of lack of business, for in every direction conditions of brisk activity are the prevailing feature, even with the increase of prices, for although consumers may not view the advance with much satisfaction, at least they know where they are. Indeed, in practically every case they have given the steel makers confirmation of existing orders at the new rates, a fact which, in itself, has had a steadying effect. The demand for ship and boiler plates continues so good that in quite a number of instances makers find themselves unable to deliver as quickly as they would like, and a delay of several weeks is not uncommon. Where export orders are concerned—and these are steadily on the increase—premiums are being readily offered for prompt delivery of ship plates, although even with this temptation some makers prefer to devote all their energies to the supply of the home markets. Home rates are as quoted last week, but for shipment overseas prices are slightly different, ship plates being 17*l.* 10*s.*, boiler plates 19*l.* 10*s.*, and angles, 17*l.*—all per ton, f.o.b. Glasgow. Orders for steel sheets are plentiful, particularly for the heavier gauges, as, both at home and abroad, stocks have been very low for some time past. Alike from the shipyards and the general engineering shops there is such a steady all-round demand for steel of every grade as to give promise of a continuance of brisk business for some considerable time to come.

Malleable Iron Trade.—In the malleable iron trade the one serious drawback to extension and development is the continued shortage of labour, a feature which is all the more astonishing when taken into account with the number of men unemployed at the moment. Under the altered conditions of labour the workers have steadily settled down to the production of highly satisfactory outputs, mainly for the home markets, although overseas' buyers are loudly clamouring for some little recognition of their wants and necessities also. In some directions the increased cost may be a deterrent to heavy purchases, but so far little evidence of this has been seen in the Glasgow area. Bar iron is now quoted 20*l.* per ton net at works, 2*s.* 6*d.* additional being asked for delivery at Glasgow stations; while for export "Crown" bars are 20*l.* net, f.o.b. Glasgow.

Scotch Pig-Iron Trade.—Pig-iron of all grades continues so greatly in demand that even the increase of price seems to have no other effect than to stimulate production—the entire output is taken up without either the slightest delay or hesitation. While foundry iron is still to a certain extent scarce, the steel works rapidly absorb every available ton of hematite. All the same, the transition period teems with difficulties both to producer and consumer, and it will take some little time before everything goes quite as smoothly as in pre-war days. With energy and enterprise, little fear is felt for the future. Export comes away slowly. For immediate delivery, No. 1 iron is quoted about 9*l.* 7*s.* 6*d.* per ton, No. 3 about 9*l.* 2*s.* 6*d.*, and hematite, delivered at works, 9*l.* 5*s.* per ton.

Defects in Gun Steel.—In discussing the defects in nickel gun steel at the February meeting of the Mining and Metallurgical Engineers, Dr. Henry M. Howe, says *The Iron Age*, suggested that possibly American metallurgists and ordnance makers had been too ready to accept nickel steel as the only proper steel for heavy guns. He felt that perhaps carbon steel, under certain conditions of production and treatment, might have met all the requirements.

60,000-Kilovolt Ampere Transformers.—The Allgemeine Elektrizitäts-Gesellschaft last winter finished one 60,000 k.v.a. transformer for the Goldenbergwerk of the Rhenish-Westphalian Electricity Works, and another transformer of the same kind and size for the same plant was nearly complete. The transformers are intended for the 50,000-kw. turbo-dynamos of the plant. The low tension is 4 times 6,250 volts, the high tension 110,000 volts. Each transformer weighs 116 tons, 66 tons being taken up by the core and coils, 15 tons by the casing, and 35 tons by the oil. The core alone weighs 40 tons and is built up of sheet iron 0·3 mm. thick; the sections of the three core limbs are elliptical. The coils are of aluminium wire; there are first two layers of low-tension coils next to the core, over them a high-tension coil, and outside two more low-tension coils, so that there are four low-tension coils altogether, which may be connected in parallel or in series. The transformer height is 5·25 m., the floor space 5·5 m. by 2·54 m. The insulating material is glax, a speciality of the company. The oil is kept in circulation under pressure, the coil for the oil being immersed in water. In the tests the iron loss amounted to 126 kw., and the loss in the hot aluminium convolutions to 434 kw., making up a loss of 560 kw.; the efficiency would thus be 99 per cent.

STEEL WORKS MACHINERY.

CONSTRUCTED BY MESSRS. DAVY BROTHERS, LIMITED, ENGINEERS, SHEFFIELD.

(*For Description, see Page* 598.)

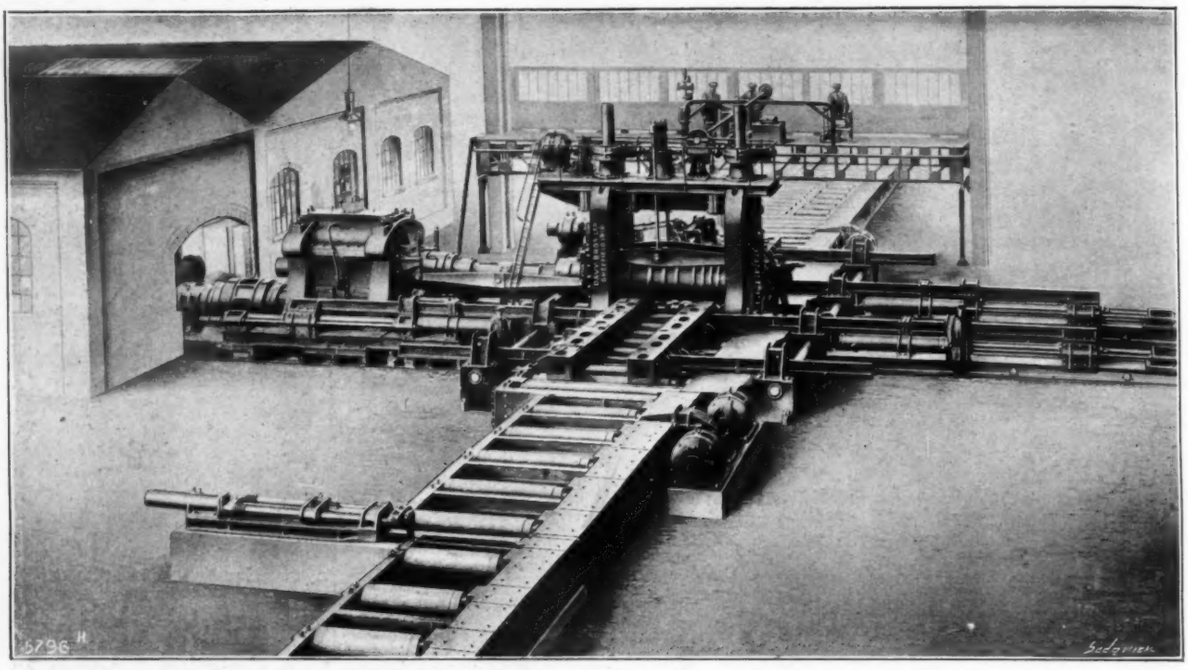


Fig. 7. 40-In. Cogging Mill; Delivery Side.

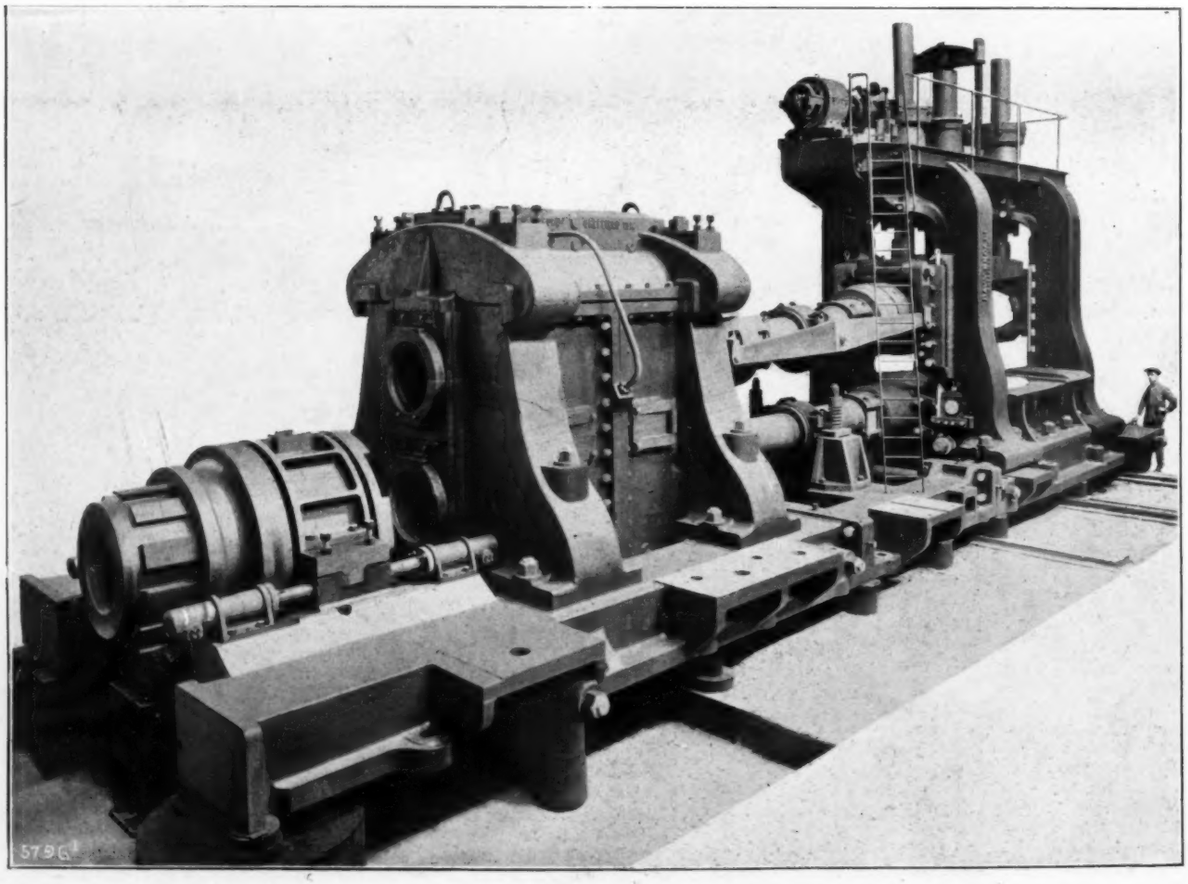


Fig. 8. Mill Train seen from Driving End.

STEEL WORKS MACHINERY.

CONSTRUCTED BY MESSRS. DAVY BROTHERS, LIMITED, ENGINEERS, SHEFFIELD.

(*For Description, see Page* 598.)

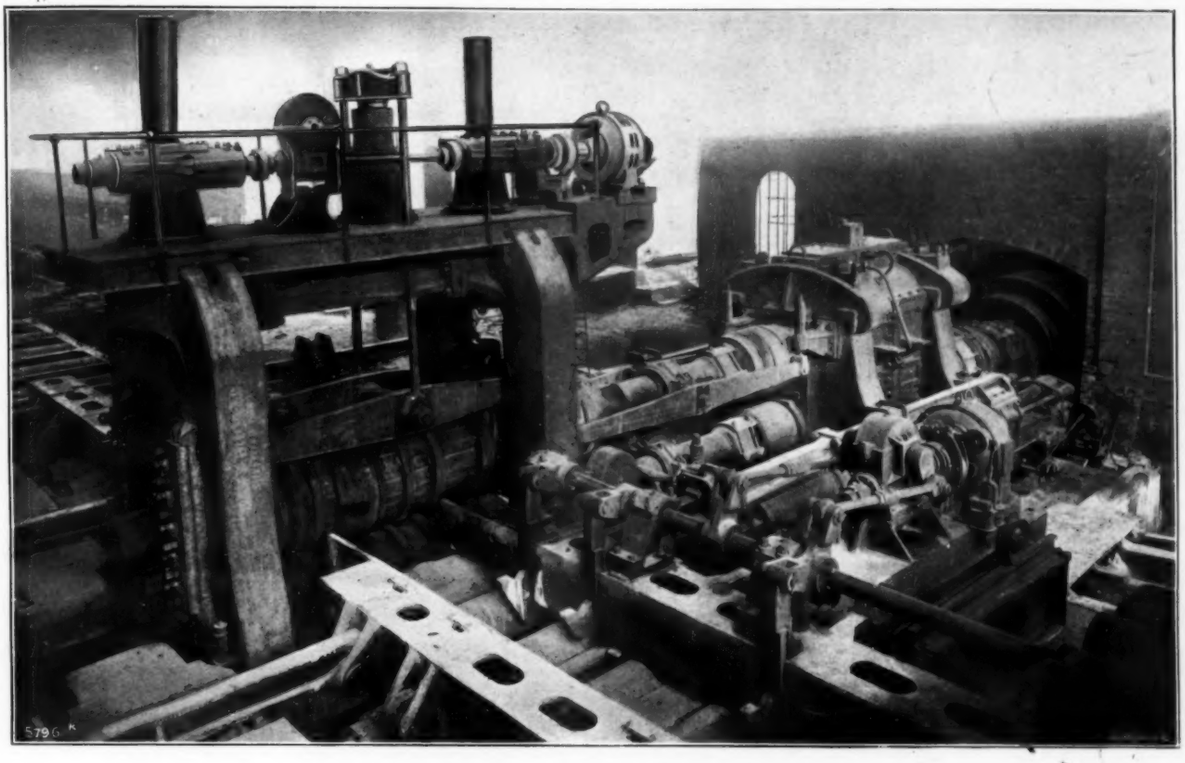


FIG. 12. 40-IN. COGGING MILL; INGOT-TILTING MECHANISM.

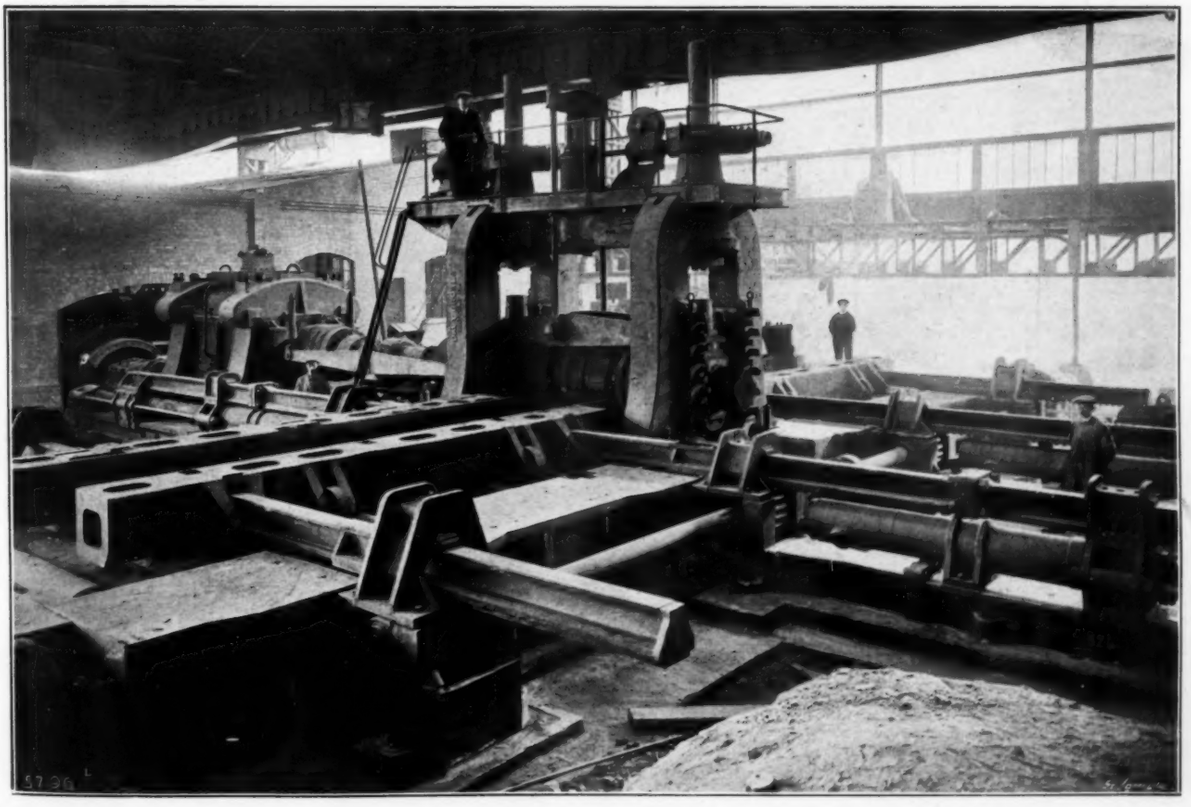


FIG. 13. 40-IN. COGGING MILL; DELIVERY SIDE.

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Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than Monday morning.

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TELEPHONE NUMBERS—3883 and 8598 GERRARD.

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With Two One-Page Plates of STEEL WORKS MACHINERY

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper and the consequent shortage of Supplies, Newsagents will not have copies for chance customers: therefore readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 605.

ENGINEERING.

FRIDAY, MAY 9, 1919.

NATIONAL ELECTRICITY SUPPLY.

ALTHOUGH the supply of electricity has been eliminated from the scope of the Ways and Communications Bill, the subject is, of course, to be dealt with by the Government, and an Electricity Bill was introduced in the House of Commons yesterday, but too late for us to have the Home Secretary's speech in introducing it. The proposals of the Government cannot be discussed until they have been fully disclosed, but the subject is of such importance and complication that it is deserving of much preliminary consideration. The question of national electricity supply naturally divides itself into two independent problems, the technical and the administrative, of which the latter is likely to prove the more difficult of satisfactory solution. In saying this we do not wish to underrate the technical difficulties and are quite clear that they will not be solved by taking a small scale map of the British Isles, dividing it up into chunks, and placing what has come to be known as a super-power-station at the centre of each.

We have been treated to so much talk about the inefficiency of our present methods of electricity supply and the necessity for grandiose schemes that the public, it is to be feared, has gathered the idea that industrial salvation lies in the scrapping of all our present plant and the installation of an entirely new system from Cornwall to Caithness. It will be interesting to consider what are the actual facts of the situation from a technical point of view. In general, in large towns and industrial areas electricity supply is already carried out in a reasonably efficient way, and we fail to believe that the electricity consumer in Manchester or Newcastle is going to obtain his power more cheaply as a consequence of an extensive network of mains in, say, Norfolk, which the local power consumption will certainly be insufficient to pay for. One readily admits that there are too many voltages and periodicities in this country and too many small stations, but the small stations have been deliberately imposed on the country by Parliamentary policy in the past, and the varied systems have largely grown up as a result of that policy. If a scheme is put down on the condition that it shall have no power to amalgamate or interwork with its neighbours, there is clearly little inducement for the promoters and designers of the scheme to arrange uniformity between its methods and those of others.

The fact that the country is suffering from too many small areas of supply and too many authorities is no reason for disbanding, or failing to take advantage of, such adequate supply systems as have grown up in spite of the Acts of 1882 and 1888. The businesslike procedure would appear to be to graft the methods of the future on to the successful methods of the present and to work, rapidly or slowly as progress may dictate, from our present best systems towards the unified system of the future. No doubt something of this kind will be done, events will force it to be done, but the fact is, we are afraid, to some extent being lost sight of in the "big talk" about cheap electricity and the progress of the future. The whole matter from the public point of view is in danger of being looked at in the wrong way, and instead of the unification and, if one wills, nationalisation of a number of important existing businesses being considered, the matter is discussed as though it were concerned with the creation of something entirely new.

If the large proposals which are in the air are carried out disappointment is certainly in store for those to whom the talk of cheap electricity is anything more than a politician's cry. Saying nothing of the efficiency of State ownership and management for the moment, why is it supposed that these State stations can generate and supply more cheaply than the City of Manchester in which we already have the blessing of public ownership and management, and an area of supply which is not ridiculous from a technical point of view. Any saving which may result from larger stations will be more than lost in the increased costs to which the depreciation of the currency have committed us. In saying this we do not wish to convey the idea that there is nothing in the large station notion. This is far from being the case, and in view of present and probably future costs of labour, coal and material, it is probably only by an adequate unified scheme, from a technical point of view, that we shall be able to obtain power at reasonable rates. It would be well, however, not to delude ourselves with too much talk of cheap electricity.

In an able paper read before the Royal Society of Arts last Wednesday, Mr. J. S. Highfield gave some interesting figures bearing on the probable cost of electricity under the new dispensation which we are to come into. Taking Mr. Highfield's most favourable figures, for a station with 25,000 k.w. generators, a maximum load of 100,000 k.w. and a load factor of 50 per cent., he gave the cost of generation per unit at 0.37*d*. For transmission at 33,000 volts by underground mains, the cost per kilowatt per annum per mile was 0.13*d*., and for overhead lines 0.08*d*. When to these figures, transforming, distribution and administration costs are added, it is clear that no improvement is likely to be shown over the selling prices of 1914, which Mr. Highfield placed at 1*d*. per unit for ordinary factory hours, ½*d*. per unit for factories working continuously and even lower prices for special purposes under contract.

Mr. Highfield's paper formed in the main a review of the present position of electricity supply in this country and of the circumstances which have made it what it is. He concerned himself mainly with the technical aspects of the question, and refrained from discussing the various recommendations which have been put forward for the control of the industry in the future. He did, however, plead that electricity commissioners should be appointed before district boards or other authorities having power of purchase or management were set up. The commissioners would examine the whole field and report to Parliament before anything was done which would seriously interfere with the industry. He pleaded also for the removal of the present uncertainty and the immediate consideration of the position of the Provisional Order Companies. The present indefinite position was holding back important extensions and seriously hampering all existing organisations. If matters were placed in the hands of such Commissioners a condition might be reached in which the industry could continue to progress and the questions of district boards, State ownership, &c., could be properly considered in due course.

With Mr. Highfield's proposal one has every sympathy. The number of commissions which have sat, and reports which have been presented on this question of electricity supply are so great that those engaged in the business may be pardoned for failing to know quite where they are. We look upon the position which at present exists as an example of a conspicuous failure on the part of the Ministry of Reconstruction, a failure which unfortunately is not unique. If that Ministry was not appointed to consider after-the-war problems during the war and to have proposals and schemes which could be produced to prevent such periods of uncertainty as electricity supply is now experiencing, for what was it appointed? Although it has been very busy with little booklets at 2*d*. each, we doubt if the production of a series of harmless essays was the ostensible purpose of the Ministry. With every respect for Mr. Highfield's opinion, we think what is now wanted is not so many electricity commissioners as the production of the Government Bill so that those concerned may know how they

stand. Therefore we welcome its introduction on Thursday and await full details of its provisions.

Although the proposals of the Government Bill are unknown there is a recent report to the Ministry of Reconstruction which we think is likely to colour it. As far as we know this is the latest to be issued of the reports dealing with this subject. Officially it is known as the "Report of the Committee of Chairmen on Electric Power Supply" (Cmd. 93). It appeared a few weeks ago. The reason we think it is likely to colour the Government Bill is that it reports practically in favour of State ownership and operation out and out, and that is certainly the direction in which the present Government is travelling on many questions. The Report adversely criticises the District Electricity Boards which Sir Archibald Williamson's Committee recommended. It was proposed that these boards should be financed some locally and some nationally, and that they should to a considerable extent represent local interest. There is much to be said for the proposal, but the Report with which we are now dealing objects to the "heterogeneous system of finance," and thinks the divided authority would "militate against uniformity of administration." To this one is tempted to suggest that one could have many worse things than a little local elasticity and possibility of initiative.

It is not necessary to criticise this Chairmen's Report in detail. One may wait to see what proposals the Government hatch from the four reports they have now obtained. There is, however, one feature of this latest report which certainly deserves mention. The report proposes an electricity board for the whole country, to consist of six members. The chairman would be appointed for five years and the other members would retire two annually, like the board of directors of a public company. The members are to be men of "proved business capacity," but it is not made clear who is to elect them. Presumably it is the Government. The next feature is, however, of most importance. This board, although it is to be subject to Parliamentary control, is to "conduct its operations on a strictly commercial basis." State ownership and management on a strictly commercial basis is, we confess, beyond us. It is a hybrid we do not recognise, and is apparently somewhat the same kind of object as a square triangle. Seriously, this sort of thing is merely silly, and we fear the Committee have invented it with the idea of trying to reconcile their knowledge as business men with some notion about the spirit of the age. If the State is going to take over electric supply let it do it honestly with no nonsense about business management. We can quite understand that Mr. W. L. Hichens, who was a member of the Committee, was unable to swallow this State management on commercial lines, and failed to sign the Report. What we cannot understand is how the other members managed to lend themselves to such a gastronomic conjuring trick.

EXCESS PROFITS DUTY.

BUSINESS people have looked forward with eagerness to the Chancellor of the Exchequer's presentment of the Budget to the House of Commons on Wednesday last, April 30. Their interest was chiefly centred on the probability of an increased income-tax and an expected alteration in the rate of excess profits duty. Now we know the worst; there is no increase in the income-tax and excess profits duty is reduced from 80 per cent. on excess profits to 40 per cent. Up to the present, no discussion has taken place on the details of the excess profits duty at the rate of 40 per cent., but it may generally be assumed that the basis of the levy will be the same as in the past, without any violent alterations. The Chancellor has not yet told us from what date the 40 per cent. rate shall start, January 1, 1919, April 1, or next July. It is a common view that the new rate will start from January 1, 1919, and that the right of apportionment will apply. Thus in accounts for six months ended March 31, 1919, the first three months will be at the rate of 80 per cent., the second three months at the rate of 40 per cent., making an average for the whole period of 60 per cent. The yield of excess profits duty during the past year 1918–19 has been a little short of 300,000,000*l.* The yield for the new year 1919–20 at the old rate of duty was anticipated to be 100,000,000*l.*, and therefore at 40 per cent. the yield is expected to be 50,000,000*l.* We should expect the new yield at the 40 per cent. rate to be much greater than 50,000,000*l.*, but in any case these figures are preparing the mind of the people for the gradual elimination, probably next year, of what is now known as excess profits duty.

Excess profits duty was originally introduced as a war measure for raising revenue, and now that peace terms will shortly be signed it is recognised by all that excess profits duty must ultimately be taken off the Statute Book. Even the most optimistic hardly dared to hope for its complete extinction this year. The reduction from 80 per cent. to 40 per cent. has given almost universal satisfaction because it is recognised that it now gives the owners of a business a greater interest in reducing costs of production, in curtailing unnecessary expenditure and in engaging in legitimate speculation and enterprise in the conduct of business.

Generally speaking, the duty is levied upon all businesses whether carried on by private individuals, firms or limited liability companies, but not including farmers, professions, and commercial travellers. The basis of excess profits duty is that a business takes as the basis of profit the average annual profit of any two years out of the three years immediately preceding August 4, 1914. To this figure, there is added in all cases a sum of 200*l.*, and this is defined as the pre-war standard of profits. In subsequent periods, called accounting periods, if the profit exceeds the pre-war standard, of such excess there has been paid to the Government from 50 per cent. to 80 per cent. according to the periods under review. For accounts which were closed between August 4, 1914, to June 30, 1915, the rate was 50 per cent.; to December, 1916, the rate was 60 per cent.; and since that date 80 per cent. If any two years out of three years before the war do not give what is believed by the owner of a business to be a fair pre-war standard he has the option, under certain circumstances, of taking any four years out of the six years prior to the war, and the average annual profit, plus 200*l.*, will be taken as the pre-war standard. Alternatively, the owners of a business have always the right to take as their pre-war standard, interest on their capital at the date of their acounts immediately before August 4, 1914, at the rate of 7 per cent. in the case of private firms, or 6 per cent. in the case of limited liability companies. Since December 31, 1916, on additional capital over pre-war capital, the rates have been increased to 11 per cent. in the case of private firms and 9 per cent. in the case of limited liability companies. In case these rates of interest are not regarded by any trades or business to afford a fair return on capital, a Board of Referees is appointed under the principal Act to consider applications for increases, and various increases have been made by the Board to the above rates.

In arriving at the liability for excess profits duty, in all cases it is necessary to find out if any new capital has been employed in the business and, if so, the firm or company is entitled to interest on such extra capital. Thus, assuming the case of a limited company whose year ends on December 31, 1918, and has made a profit of, say, 15,000*l.*, such profit is reckoned to have been made on the capital at the beginning of that year, say December 31, 1917. The capital on this latter date is arrived at, generally, by taking the total assets employed in the business and deducting the total liabilities to creditors for goods, loans, mortgages, &c., leaving a capital of, say, 70,000*l.* The average capital of the pre-war years arrived at in the same way was, say, 55,000*l.*, giving an increased capital of 15,000*l.*, which, at 9 per cent., gives a charge for interest of 1,350*l.*, and which, deducted from the 15,000*l.* profit shown by the accounts, gives for excess profits duty purposes only a profit of 13,650*l.* From this must be deducted the pre-war standard, and then 80 per cent. of the balance is handed over to the Government for excess profits duty. If during the year ended December 31, 1918, the firm or company has withdrawn from the business large sums for private drawings or investments, or for the payment of dividends, then the surveyor of taxes will seek to reduce the capital of 70,000*l.* by the amount of such sums on the basis of one year; thus a withdrawal of 6,000*l.* on May 1, 1918, would be equivalent to 4,000*l.* for the year; and would be deducted from the 70,000*l.*, and in that way save the Government 80 per cent. of interest at 9 per cent. on 4,000*l.*, equals 288*l.* net. For ordinary withdrawals, however, this deduction may be saved if it can be proved that the accruing profits for the year 1918 are equal or in excess of such drawings. On the other hand if, instead of a withdrawal of 6,000*l.* on May 1, 1918, there was a payment made into the business on capital account of 6,000*l.*, it would add to the capital of 70,000*l.* at December 31, 1917, a sum of 4,000*l.*, and thus give a charge against the Government of 80 per cent. of interest at 9 per cent. on 4,000*l.*, equals 288*l.*

The item of goodwill in the assets of a limited liability company is not always dealt with in the same way for capital purposes. If the shares are held by the original proprietors of the business, then goodwill will be deducted in arriving at the capital employed; on the other hand, if the majority of shares is held by the general public (not the original proprietors) the goodwill will be allowed as part of the company's capital. It was originally the intention of the Government that no person should be liable to excess profits duty who, during the whole period of the operation of excess profits duty, had not made excess profits, but the practice of the surveyors of taxes is to take in each period of accounting the excess profit made, apply the rate of duty ruling, and then call upon the firm to pay or carry forward the deficiency to later periods. This has the effect of making a firm or company in certain cases pay excess profits duty when there has been no excess profits. Thus, suppose annual pre-war standard profits were agreed at 2,000*l.*; profit for first accounting period year to June 30, 1915, 1,500*l.*; deficiency 500*l.* at 50 per cent. to carry forward, equals 250*l.*; profit for second accounting period year to June 30, 1916, 2,500*l.*; excess profit, 500*l.* at 60 per cent., equals 300*l.*; less deficiency brought forward, 250*l.*; net liability to pay, 50*l.* The profits in accounting periods were 1,500*l.* and 2,500*l.*, making 4,000*l.* for two years, so that there have been no excess profits made, and yet because of the variation of duty there is a liability to pay. It should be said that the amount of excess profits duty is always allowed as a proper item of expense in the accounts when ascertaining the liability for ordinary Income-Tax Schedule "D."

The question is often asked as to the amount which will be allowed in a firm or company's accounts for directors' or managers' salary and commission. For ordinary income-tax all these payments will be allowed if properly made by the company. The allowance of these items to the firm or company reduces its income-tax liability, but increases by a similar sum the individual liability of the director or manager. For excess profits duty purposes, however, the procedure is different. Assuming that a manager or director has not a controlling interest in the business (which generally means with the aid of his friends about one-half of the shareholding) he will be allowed the amount which he had in the pre-war year plus a further sum based on the extra services rendered and the amount of additional profit made, but in no case will such further sum exceed 2,000*l.* per annum. If such director or manager is in receipt of directors' fees from any new company with which he was not connected before the war, his fees must be deducted from the 2,000*l.* referred to above. The intention is to make the 2,000*l.* extra, inclusive of all income from business appointments. If the manager or director has a controlling interest then no extra amount for remuneration will be allowed; he will be treated in the same way as a proprietor or partner in a firm where no extra amounts are allowed for services.

At the beginning of excess profits duty some firms sought to avoid payment of large sums of excess profits duty by voting sums to directors or managers, sometimes relatives, in the business, presumably for extra services, but this was open to great abuse, and it was only right that this should be stopped in the interests of the whole community. There may be, and are, cases where this may act harshly

and unjustly, but if we are to compare "like with like" it must be conceded that the limitation is not unfair. Where the greatest hardship is felt is in the case of a director or manager having a pre-war agreement and not being allowed for excess profits duty purposes all the commission or remuneration to which he is entitled under such agreement. It is understood that a test case will shortly come before the Courts bearing on this point.

Considerable difficulty is now being experienced by some firms in paying the liability for excess profits duty, when ascertained. Whereas before the war they could comfortably do their business, say, on a capital of 20,000*l.*, they now find that because of the large increase in the cost of materials they have to carry stocks for the same business of three or four times the former values, with the result that they have not the same financial freedom as before. In addition to this, some firms have devoted their profits to extensions of buildings and plant in order to increase output. In these cases, the Inland Revenue, on satisfactory grounds being proved, are willing to allow extended payments.

From July 1, 1915, onwards, certain businesses became what is known as "controlled" businesses. The chief points of contrast between the controlled and uncontrolled businesses were: (1) The controlled business was to have preferential treatment regarding a sufficiency of workpeople to carry on. (2) The controlled business, up to December 31, 1916, was brought under the scope of the Munitions Act. Under this Act the controlled business might have a different standard as the basis of its pre-war profit, if in favour of the State, with the right, however, to special allowances for depreciation on buildings and plant and machinery erected or purchased for war work. After December 31, 1916, all controlled businesses came under the Finance Acts for excess profits duty like all other firms, with this exception, that the controlled firms are still entitled to the special allowances for depreciation on buildings, plant and machinery, erected or purchased for war work.

It is generally admitted that excess profits duty at 80 per cent. did not give any incentive to manufacturers to extend their businesses, but was the direct cause of waste and extravagance. When a manufacturer felt he had made his standard profit he had no great enthusiasm in making further profit, because he only shared in such extra profit to the extent of 20 per cent. less income-tax. Nor was he encouraged to be too prudent in his expenditure, knowing that 80 per cent, was borne by the State. A new industry was not likely to be too enterprising because its standard profit was only fixed at 9 per cent. or 11 per cent. on its capital, with probably an allowance for the owner's former salary. There are some businesses carrying very heavy stocks at high prices. Prices are in many cases on the down grade, and by retaining excess profits duty at the rate of 80 per cent. it would have enabled these firms to recoup these losses from the Government, if their profit was reduced below the pre-war standard. Under the new Budget any deficiency in profits as compared with pre-war profits will only be repayable to the taxpayer at the rate of 40 per cent., whereas during the past two years, when stocks have risen in value, any excess has been payable by the taxpayer at 80 per cent. At the beginning of excess profits duty it was thought an injustice to tax those firms whose year ended, say, August 31, 1914, or even up to December, 1914, because excess profits duty was supposed to be a war tax, and in most businesses no war profit could be included in these accounts. It is the intention of the Government, however, to make each firm liable for the same number of periods, and therefore, when excess profits duty comes off, those firms will come off first who went on first, and those who were longest in coming in for assessment will be longest in receiving the last assessment.

PERSONAL.—The Institute of Cost Accountants, Limited (by Guarantee) give notice that they have now moved to more suitable premises, from where all communications will be dealt with. Applications for particulars of examinations and conditions of membership should be addressed to the Secretary, 17, Victoria-street, Westminster, London, S.W. 1.—The Electrical Research Committee have appointed Mr. E. B. Wedmore as Director of Research.

NOTES.

ENGINEERING AND SHIPBUILDING IN NEW SOUTH WALES.

THE report of the Department of Public Works of New South Wales, for the year ended June 30 last, gives interesting information on the provisions made for the building and repairing of ships in the Commonwealth. The Cockatoo Island Dockyard, where the bulk of State repairing and construction work was formerly carried out, having been taken over by the Commonwealth Government on February 1, 1913, it was found necessary to provide another establishment where this class of work could be continued. Walsh Island, Newcastle, was fixed upon as the most suitable and central situation; a commencement was made with the construction of workshops in March, 1913, and the official opening ceremony took place in November, 1914. The works now include a machine shop, pattern shop, boiler shop, brass foundry and finishing shop, bridge-building shop, erecting shop, iron foundry, coppersmiths' shop, galvanising shop, blacksmiths', joiners', painters' shops, shipyard, docks, slips, laying-down loft, stores and tool rooms, offices, wharves, cranes, tramways, &c. Considerable work has already been carried out, including the building of new dredging plant, repair work, the building of steel railway and road bridges ready for erection *in situ*, and miscellaneous engineering work. It was realised that Walsh Island provided excellent facilities for the construction of merchant vessels, and following the agitation for the institution of a vigorous shipbuilding policy early in 1917, the Federal authorities inspected and reported favourably upon the general lay-out of the island, but no definite proposal was made by the Commonwealth Government for operations to proceed. In the meantime, the Broken Hill Proprietary Company approached the New South Wales Government with the object of securing a lease of the establishment for an extended period, with the right of subsequent purchase, for the express purpose of giving effect to a contemplated shipbuilding programme. The negotiations fell through, and after further considering the matter, it was finally decided that the Government of the State of New South Wales should retain the establishment and accept a contract to build ships for the Commonwealth. The contract was entered into on March 27, 1918; it provides that the State shall, under the supervision of the Commonwealth Government, construct, launch, try under steam, and deliver to the Commonwealth at wharf, Walsh Island, six steel cargo steamers, each 331 ft. in length B.P., 48 ft. beam and approximately 5,500 tons deadweight capacity, built ready for sea in accordance with the plans furnished by the Commonwealth, the contract price for the ships being computed at the rate of 28*l.* per ton deadweight capacity. This figure may be subject to modifications in circumstances detailed at length in the agreement. It is also stipulated that the Commonwealth Government may at any time, before delivery of the third steamer, call upon the State to construct and deliver two substituted vessels, each of a capacity not exceeding 8,000 tons, in place of two of the smaller type vessels. In conformity with the agreement, work has been undertaken at the dockyard; the keels of three vessels have been laid, and operations are proceeding, but it is regretted that delay in the supply of materials ordered by the Commonwealth from America has prevented the work from being as far forward as would otherwise be the case.

DETERMINATION OF THE ELASTIC LIMIT.

Professor O. Lehmann, who has made a speciality of the study of liquid crystals, has devised a new method for determining the elastic limit of bodies. Though chiefly proposed for the distinction between soft solid crystals and tough liquid crystals—a distinction which is sometimes difficult, in the case of ammonium nitrate, for instance—the method is interesting with respect to the considerations on which it is based. Only solids have an elastic limit; in the case of liquids the elastic limit is zero. In order to understand the elastic properties of crystals, Professor Lehmann argues with Poisson, the crystal molecules must possess directive forces, though he states that some X-ray workers (Bragg, Rinne and others) believe that central atomic forces (valencies) will suffice. When the space-lattice is disturbed by bending the crystal, the deformation is opposed by the elastic force which must be compensated by external force. When we force a crystal bent to the shape of a ring into a cavity, which the ring fits exactly, the crystal will behave like a compressed spring, and as long as the elastic limit has not been exceeded, the counterforce will remain constant, and the ring will at once resume its original shape after removal from the cavity. When the elastic limit has been exceeded, there will be a gradual relaxation, and the counterforce will very slowly approach the limit asymptotically. In that way the elastic limit might be determined, but it would be very difficult. After trying another method Lehmann resorted to the shrinkage of a hollow sphere, containing air or a vacuum, under uniform (hydraulic) pressure. A very thin sphere would shrink to a certain extent until the counterforce balanced the external pressure. A second sphere, inside the first, would likewise shrink, both less than one alone, however. If the sphere were massive, there would be an inner core into which the external pressure would not penetrate. The equilibrium would not be changed hence, if we removed that core, and that is the case of a tunnel driven through a mountain; as long as the pressure does not exceed the elastic limit, the tunnel will not be crushed in. When the external pressure exceeds the elastic limit, the hollow sphere will shrink more and more in the course of time; but there will always remain a core into which the pressure is not propagated, provided the material have an elastic limit greater than zero. In that case again, then, the core might be removed. The greater the outer pressure, the smaller that core; when there is no elastic limit, the core will vanish completely, even with the smallest pressure, sufficiently long applied—presuming the core to be empty and not filled with air. When the material is a homogeneous crystal, possessing different elastic limits in different directions, the shrinkage will be accompanied by a change in shape. A crystalline wax, *e.g.* (a mixture of several materials) will turn rough if originally smooth. When we create a vacuum in the centre of the body, the existence of an elastic limit, and the solid nature of the material, will have been established if the cavity will not quite vanish; the cavity will approach a minimum depending upon the pressure. Even this method would require experiments of very long duration, however, to yield definite values for the elastic limit. But we may conclude that there is no elastic limit (and the body hence a liquid), if the cavity should disappear completely under some conditions. In his experiments—which are very briefly noticed in Lehmann's communications to the German Physical Society, 1918, pages 63 to 68—he uses, instead of a sphere, a space, confined within a metal ring, between two parallel glass plates, object glasses about 6·5 cm. in diameter; a capillary tube connects this space with the air or with a pump. With some liquid crystals the force of the surface tension suffices to make the hollow space vanish completely.

JAPANESE SHIPBUILDING.—Last autumn, according to *The London and China Telegraph*, there were almost 90 shipbuilding yards at Osaka, and, although early last autumn one or two yards were closed on account of the shortage of materials, the shipbuilding industry at Osaka had continued very prosperous. With the signing of the armistice, the market conditions became suddenly unfavourable, and about 10 yards were closed immediately after the signing of the Truce Treaty in anticipation of a serious depression in the wake of the armistice. By the end of December, 49 shipbuilding yards had been closed at Osaka alone. Several yards are now being still operated for completing ships under construction or executing the outstanding orders. Since the beginning of the year, the Kibi, Shigi, Chitose, Akashi, and Shikabayashi shipbuilding yards have been closed. The Fuke and Naniwa yards have recently announced that when the ships under construction at their building berths are completed, they will shut down their works altogether. The majority of the yards which have been closed up to the present were only temporary yards, and those which still remain are mostly semi-permanent yards, and they apparently intend to maintain their works, tiding over the present depression with the rich profit they gained during the war. Due to the recent general depression on the market, even many of these semi-permanent yards are in a precarious condition and may close at any time.

THE EXAMINATION OF MATERIALS BY X-RAYS.

(*Continued from page* 578.)

In proceeding with our notice of the general discussion on "The Examination of Materials by X-Rays," held on April 29 by the Faraday Society and the Röntgen Society, we should mention in the first instance that we reprint the contribution, mentioned last week, by Mr. E. Schneider, of Le Creusot, on "X-Ray Examination in the Laboratories of Messrs. Schneider," on page 513 of the present issue.

Radiometallography.

The appliances used at Creusot are supplied by Messrs. Pilon, and further information on these apparatus and their use was given in a paper on "Radiometallography" by Mr. Hector Pilon and Mr. Geoffrey Pearce, of Messrs. Watson and Sons, Sunic House, Kingsway. The paper was read by Mr. Pearce, who stated that they had been able actually to penetrate steel in thicknesses up to 55 mm; with greater thickness the exposures became too long.

Under similar conditions, the same energy input, same potential and current, same distance, &c., a single block of a metal requiring an exposure of 30 seconds for a thickness of 15 mm., would require 250, 2,000, 3,500, 4,800, 6,500 seconds for thicknesses of 25, 40, 45, 50, 55 mm.; thus a few millimetres made a great difference. In metal examination potentials of more than 100,000 volts were frequently employed, and for the present further perfection of the apparatus and photographic methods seemed to be the chief problem. For high penetration induction coils yielding 6 milliamperes at 150,000 volts with a spark gap of 30 cm. seemed to be the most suitable; under 120,000 volts, 4 milliamperes were sufficient. The mercury-jet interrupters were better worked with hydrogen than with coal gas, especially for heavy currents. Where high generation was not essential, transformer and rotating rectifier-discs, the latter for 106,000 volts were used; in other cases either two valve tubes or one kenotron were recommended.

As regards the photographic side, reinforcement of the effect and elimination of all superfluous rays had chiefly to be studied. With the aid of one intensifying screen the degree of intensification could be raised 15 times; by placing the photographic film between two screens, they had determined differences in thickness of 0·1 mm. through 45 mm. of steel. Another advantage secured by these means was that the grain of the crystals in the intensifier—a feature we mentioned last week—was suppressed on the plate; the uneven nature of the crystals created a uniform field. Excellent results had been obtained with films sensitised on both sides. The film had the distinct advantage over the plate that it was flexible.

Fig. 1, annexed, is a reproduction of a radiograph of the entire cylinder of an aeroplane motor, which was obtained by placing four films inside the cylinder; the picture is a positive and the dark parts indicate greater wall thickness. The film could also be mounted in the following way. A base was formed of some polished or silvered metal; on this surface the reinforcing screen was placed, the phosphorescent metal on the top so as to be in contact with the film itself resting on it; on the film the second screen was laid, and on this screen finally the specimen was placed. In order to shut out stray radiations, the specimen was all surrounded with lead, 5 mm. in thickness. When the specimen was irregular in shape, very fine lead shot was used, which also covered the photographic plate to a depth of at least 15 mm. or 20 mm. This shot should, of course, not be allowed to get between the specimen and the plate, and to prevent that, the specimen was embedded in transparent wax (or plasticine), the wax being trimmed off so that the object rested properly on the plate, on which the lead shot could then be piled; the photographic plate itself was placed over a sheet of lead. Mr. Pearce exhibited a radiograph of a jagged piece of ore-bearing rock obtained in this way, an application of X-rays which deserves attention. That the observation of these precautions repaid itself was evidenced by the radiograph of the base of a 75-mm. shell; this base looked quite uniform, but there was a faint white spot near the centre, marking an invisible weakness in the metal which the pressure test had not revealed.

Mr. Pearce then explained with the aid of slides the arrangements adopted for the protection of the operator. In Messrs. Schneider's works at Harfleur (near Le Hâvre) the operator stood in a cabin, the walls of which were lined with 5 mm. of lead, safe from the radiations which would spread through the whole room, but able to watch the X-ray bulb through 10 mm. of anti-X-ray glass or with the aid of small lateral windows and mirrors. When working at more than 80,000 volts, a lead shutter was pulled down in front of the window, or the bulb was placed within a lead-lined box, a mirror being again used for watching the operations; this was the arrangement made for the examination of carbon electrodes and brushes by the Compagnie des Charbons de Nanterre.

We reproduce some of the other interesting slides shown by Mr. Pearce. Though neither the atomic weights of iron (55·8) and nickel (58·7), nor the densities (iron 7·88, nickel 8·9) differ much, Fig. 2 marks strong differences in the shadow depth of this radiograph; the specimen was prepared by embedding a nickel core in iron and planing the two metals down to the same thickness. In an aluminium gear case a defect had been stopped by aid of solder; the flaw came out as a dark spot. Fig. 3 shows the two halves of the bearing of an aeroplane motor, consisting of steel lined with white metal, the latter being held in position by the holes made in the steel; these holes are round, but appear elliptical and rather diffused in the one diagram because the radiation was not normal to the surface. The feature to which Mr. Pearce drew attention is, however, the streaking of this diagram; the streaks were not due to any want of surface finish, but to a faulty composition of the white metal. The carburettor of an aeroplane motor, shown in Fig. 4, was defective in operation. We are not sure that we can trace the defect in the petrol-feed canal which the photograph was said to reveal; but the radiograph, taken with an exposure of only 2 seconds and with the carburettor at the large distance of 125 cm. from the target (in order to avoid distortion) is certainly a remarkable exemplification of the possibilities of stereoscopic radiography. Mr. Pearce mentioned that they had taken radiographs of the internal parts of an explosive body, 25 cm. in diameter, made of steel, 12 mm. thick, and had often been called upon to examine shells, fuses and torpedoes, by means of X-rays. The radiograph of the current distributor of the magneto of an aeroplane motor, Fig. 5, is again remarkable though we are afraid that our readers will not be able to distinguish the segments of the commutator, visible on the original, nor the exact nature of the defective contact which was located by the X-rays, and which is marked by an arrow in Fig. 5.

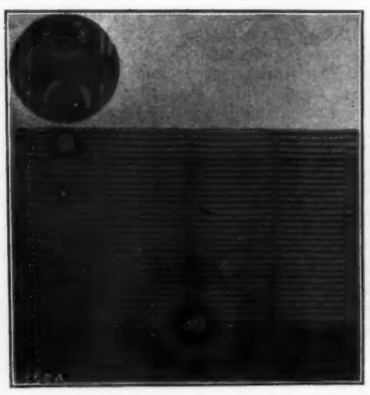


Fig. 1.

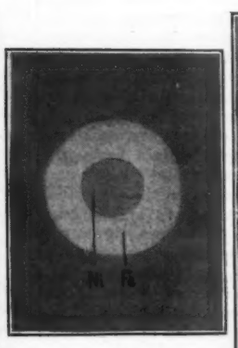


Fig. 2.

Fig. 3.

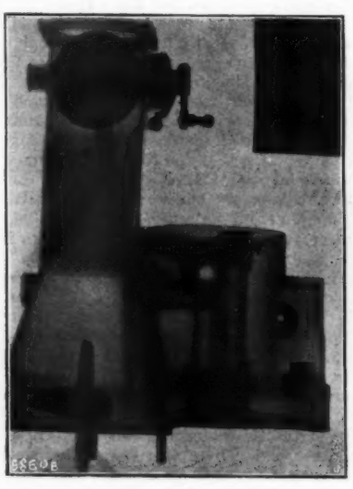


Fig. 4.

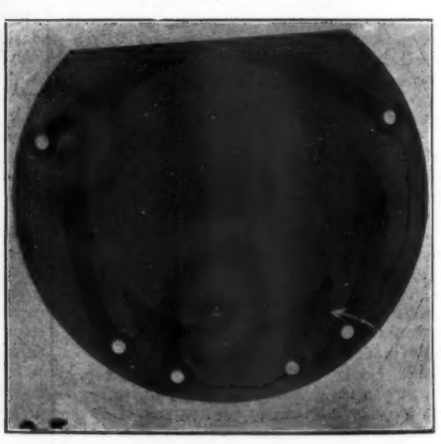


Fig. 5.

On behalf of Major J. Hall-Edwards, F.R.S.E., Professor Thomas Turner, of Birmingham, then exhibited some striking radiographs of aluminium castings, mentioning that experiments on brass and other alloys were being proceeded with. We hope

to reproduce some of these radiographs on an early occasion.

X-RAY EXAMINATION OF AIRCRAFT TIMBER.

What X-rays can do in the examination of aircraft woodwork, where the choice of unsuitable material, oversight, carelessness or the concealment of apparently slight mistakes may lead to obscure and fatal accidents, was very forcibly demonstrated in a paper by Captain R. Knox, M.D. (hon. secretary of the Röntgen Society), and Major G. W. C. Kaye, R.A.F., D.Sc., on "The Examination of Aircraft Timber by X-Rays." About the middle of 1918, Major Kaye stated, the Aeronautical Inspection Department decided to utilise X-rays for timber inspection. The equipment of the Cancer Hospital was used, and the results were very encouraging. Owing to the severe pressure the method had not yet reached the stage of commercial application at the time of the armistice, but the remaining problems were chiefly of equipment, portability and similar matters. Expressing their great indebtedness to Lieutenant Hudson-Davies and also to Mr. G. F. Westlake, Dr. Kaye explained that they had from the outset recognised the need of rapid visual examination by fluorescent screens, reserving photography for recording cases which the screen had shown to be of interest. As all woods were transparent to X-rays, soft tubes, and spark gaps of 1 in. or 2 in., were sufficient; the output of soft tubes being small, and fluorescent screens requiring excitation by rather hard rays, however, rays as hard as feasible, transformers and Coolidge tubes for 15 milliamperes were used in this testing.

Examinations were made both of the material in the rough condition and of the assembled parts. In aeronautical timber the chief defects to be looked for were spiral grain (in spruce and its substitutes), hidden knots, resin pockets, compression shakes, incipient decay, grub holes, and very light woods. As regards differences in density, due to knots, resin, grub holes, &c., no difficulty was experienced; the other defects were more difficult to detect in thick specimens. The rays chiefly brought out the differences in density between the light spring wood and the denser summer growth, *i.e.*, the annual rings; practically that knowledge was useful only in marking localised hard grain which was objectionable for aircraft purposes. In a radiograph of silver spruce, taken tangentially to the rings, the grain-effect was rope-like, the curious criss-cross effect being due to the presence of "figure" caused by the elongated depression on the annual rings repeated from year to year. Other radiographs exhibited exemplified the slant of the fibre and the glue-joints. On the whole, however, the X-rays did not tell the expert much more as to the timber and semi-finished parts than he could discover by visual inspection; but experts were rare, and semi-skilled inspection would be facilitated by the method.

Passing to the examination of finished and assembled parts, Dr. Kaye remarked that the method was particularly useful for the study of parts, not made of solid wood, but constructed on the laminated or box principle. That construction had become necessary when the supply of high-grade timber had been endangered; smaller timber could be utilised, but the difficulties of inspection were much increased. With that construction defects could be concealed, and unscrupulous and careless workmen were aware of the fact. Notices had been displayed in aircraft factories: "A concealed mistake may cost a brave man his life." In spite of grave difficulties of labour and material, British aeroplanes were superior both in quality and numbers to those of any other nation. But there was a tendency to hide mistakes, the grave nature of which was underrated, and the vigilance of the inspectors had prevented many accidents.

FIG. 6.

FIG. 8.

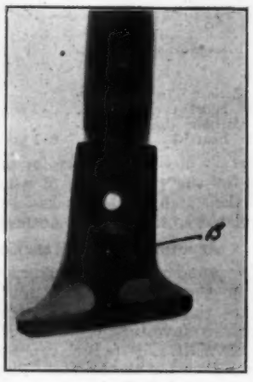


FIG. 9.

In most of the important parts, main-plane wing spars (from end to end of each wing); compression struts (between the two spars of a wing); interplane struts; and longerons, cross-struts and engine bearers (making up the fuselage) the composite construction was permissible. But the strut or spar was completely covered with fabric, veneer or ply wood, and visual inspection was ineffective, unless the inspector could manage to stand over the job all the time.

We select a few of the characteristic radiographs exhibited. Fig. 6 shows the end of a hollow box-strut; the internal strengthening block was badly fitted, each of the screws had split the wood, and the work was altogether discreditable and insecure. Poor workmanship is also manifest in the cutting of the internal strengthening block of the hollow main-wing spar of Fig. 7. The side view of a hollow aileron spar showed the spar to consist of two halves glued together down the centre after the sides had been spindled out; the two halves of the block should register accurately and the sides should be equally thick. In reducing the glued spar to finished dimensions workmen were, however, apt, Dr. Kaye explained, to plane away more wood on one side than on the other, thus reducing the strength.

In some other photographs (not reproduced) the X-rays at once revealed that the halves, which should consist of the same wood, had been made of different materials. The laminated spar, shown in front and side view in Fig. 8, was made up of three laminæ glued together; the external appearance was excellent, but the X-rays disclosed large knots and a grub-hole in the middle layer which would have weakened the spar to a dangerous degree. Fig. 9 exemplifies another kind of reckless work. The wooden skid (top of photograph) had been cut off too short properly to fit into its socket; to make up the length a piece of packing B had been introduced into the space below. In a wing skid like the one shown this would not be a vital matter, but the same practice had been resorted to in interplane struts. The skid socket, Dr. Kaye added, was aluminium, in. thick, and the radiograph was taken with a current of 10 milliamperes and a spark gap of 8 in. A similar case was more serious. The internal compression strut did not enter its steel socket (1/20 in. thick) properly and had left an empty space; externally nothing indicated a defect, but the effect of the bad fitting would be that under vibration the strut would gradually work its way into the bottom of the socket, and the straining wires would become slack. Other radiographs illustrate a common defect. When the holes for bolts, crossing parts to be assembled in various directions, are not carefully bored, two bolts may foul one another; the detection of one such fault led to the rejection of dozens of completely finished main-wing planes. The defective riveting and soldering of the end of a steel petrol tank of an aeroplane (Fig. 10) might have attracted notice; but other cases, which Major Kaye illustrated, rivets of a tank which had heads on the outside only (none inside), and cracks in split longerons, cleverly hidden by gluing a shaving over the sand-papered surface, would have escaped notice without the X-rays. The latter have also been of great assistance in tracing the causes of accidents.

FIG. 7.

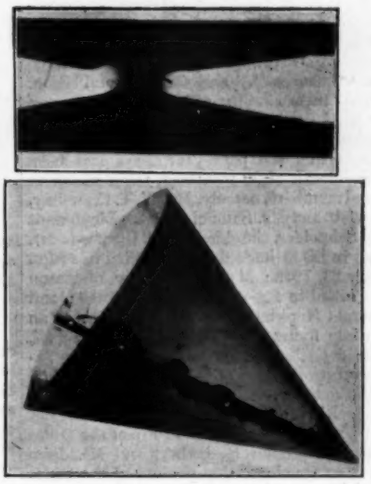


FIG. 10.

(To be continued.)

SPECTRUM ANALYSIS AND ATOMIC STRUCTURE: ERRATUM.—We regret that a correction had been overlooked in the second column of page 562, in the seventeenth line from the bottom. The sentence beginning in the twenty-first line from the bottom should read: With particles travelling at one-hundredth the velocity of light the change in frequency should indeed amount to one-third of a per cent. of its value [*not*, one-third of its value].

THE HUMAN EYE.—In the first of a series of lectures on the human eye recently delivered to the Optical Society by Mr. J. W. French, B.Sc., some particulars were given of the variations of the pupil with varying illumination of the whole retina, of the *Macula Lutea* (yellow spot), and of several zones of constant area on the retina. It appears that for the *Macula Lutea*, the pupil area varies as the fifth root of the illumination. The zone round the *Macula Lutea* is more sensitive and the sensitiveness diminishes towards the margin of the retina. So far as the pupil reflexes are concerned the two eyes are quite independent of each other, the pupil area of one eye, under constant illumination, remaining constant, while that of the other eye, subjected simultaneously to illumination of varying intensity, varies in accordance with the above-mentioned law. The variation of the pupil area with accommodation was also dealt with, and, from investigations made, it appears that this type of variation is quite independent of the illumination, and is determined by the refractive power of the crystalline lens.

THE IRON AND STEEL INSTITUTE.

THE fiftieth annual general meeting of the Iron and Steel Institute is being held this week in the hall of the Institution of Civil Engineers, by permission of the council of the latter body.

An interesting event took place on Wednesday, when Mr. Eugène Schneider, the President, and Sir William Beardmore, Bart., Past President, were presented with the freedom of the Blacksmith's Company, one of the old livery companies of the City of London.

The Institute meetings commenced on the 8th inst., at 10.30, and is being continued to-day. The President, Mr. Eugène Schneider, occupied the chair.

THE ANNUAL REPORT OF THE COUNCIL.

The minutes of the former autumn meeting having been agreed to, the chairman called upon the secretary to read the annual report of the council. This opened by stating that at the annual meeting on May 2 last year, Mr. Eugène Schneider entered into office as president, in succession to Sir William Beardmore, Bart. His accession to the presidential chair was warmly welcomed by the members as a mark of the close co-operation between the metallurgists of France and Great Britain in their common resolve to devote their energies to the assistance of their respective Governments in the prosecution of the war to a successful and speedy termination.

The total membership of the Institute on December 31, 1918, was stated to be 2,098, a total which includes the patron and four honorary members. During the past year there had been recorded the death of 33 members, three of whom were original members, namely, Mr. W. T. Crawshay, Mr. A. Hewlett and Mr. Samuel Lloyd. Lieutenant Henri Paul Schneider, the eldest son of the president, and partner in his father's firm, was killed in action on February 23, 1918; Mr. F. L. Shirley, of Briton Ferry, was killed in action on August 1, 1918; and Major Bertram Hopkinson was fatally injured in an accident while flying near London on August 27, 1918. The council then offered their congratulations to several members of the Institute who had received distinctions:—

Sir Hugh Bell, Bart., past-president, had had conferred upon him the Companionship of the Order of the Bath. Professor H. Hubert and Mr. John Craig had been appointed Companions of the Order of the British Empire. Mr. Pierre Brenil and Lieutenant Jean Schneider had been appointed Chevaliers of the Legion of Honour. Lieutenant-Colonel J. G. Needham had been awarded the Distinguished Service Order, and Lieutenant Charles Schneider the Croix de Guerre. The Military Cross had been conferred on Captain F. Webster. Professor J. W. Richards had been appointed Member of the Civilian Naval Consulting Board of the United States Government.

FINANCE.

The statement of accounts for the year 1918 showed the total receipts, excluding the income derived from the Carnegie Research Fund, to have been 5,792*l.*; the expenditure during the same period had been 6,128*l.* The receipts on account of the Carnegie Research Fund were 1,009*l.* and the expenditure 530*l.*

COMMITTEE WORK.

During the year several of the Technical Committees appointed by the council in 1917 held meetings. An interim report on Blast Furnace Practice was presented by Committee No. 2 at the May meeting, and discussed. The points dealt with in this report were the effect of the mechanical and chemical conditions of raw material on the furnace working, and the influence of the dimensions of the bell in relation to the stock line. The use of double bells, the size and quality of firebricks, and the use of waste gas for calcining ironstone were also reported upon, and several members of the committee presented papers dealing with various phases of blast-furnace practice at the meeting in question and at the autumn meeting.

Committee No. 3 had appointed a sub-committee on Open-Hearth Furnace Design, and had held two meetings. It had also been instrumental in securing several very valuable papers on steel works practice for reading at the meetings.

The Sub-Committee on Standard Steels appointed by Committee No. 5 had held three meetings, and had set up an organisation whereby steel works and their laboratories, the various universities or equivalent institutions, as well as commercial laboratories and analysts in various centres of the steel industry, would collaborate with the National Physical Laboratory in the preparation of the standardised samples. It was hoped that the various steel works would generously provide the necessary ingots or bars for the production of the samples, and allow their chemists and laboratories to collaborate for this purpose, free of charge. Definite promises to this effect had already been received from a number of important firms.

In order to carry out efficiently the work at various centres, a number of "District Authorities" had been constituted in London, Sheffield, Middlesbrough, Birmingham, Glasgow, and South Wales. Universities, or equivalent institutions; works and commercial laboratories in each district were represented on these bodies.

The first work of the committee would be the preparation of standards for sulphur, phosphorus and carbon, six steels with the following approximate proportions of the elements being under selection for the preparation of the standards:—

Sulphur	0·03 per cent. and 0·07 per cent. respectively.
Phosphorus	0·03 per cent. and 0·07 per cent. respectively.
Carbon (acid open-hearth)	0·7 per cent.
Carbon (basic open-hearth)	0·1 per cent.

Details of the procedure for selecting the ingots and for the preparation of samples for analysis and their standardisation had been drawn up and circulated to the District Authorities.

APPOINTMENT OF REPRESENTATIVES.

The president continued to represent the Institute on the General Committee of the Royal Society for administering the Government Grant for Scientific Investigations. Sir Hugh Bell, Bart., and Sir W. H. Ellis, G.B.E., represented the Institute on the Board of the National Physical Laboratory, and Sir Hugh Bell also continued to act as representative on the Board of Governors of the Imperial College of Science and Technology. On the British Engineering Standards Association the Institute was represented by Dr. Arthur Cooper, Mr. G. Ainsworth, and Mr. Illtyd Williams, and Mr. Charles Dorman continued to serve on the Engineering Standards Sub-Committee for the Standardisation of Galvanised Sheets, and Mr. R. E. E. Spencer on the Sub-Committee for Special Steels for Motor-Car Construction. Mr. H. J. Yates had been appointed to serve on the Sub-Committee for Cast-Iron, working under the direction of the Sectional Aircraft Committee. Sir William Beardmore, Bart., and Mr. G. Ainsworth continued to represent the Institute on the Technical Committee of Lloyd's Register of British and Foreign Shipping, and Mr. J. H. S. Dickenson represented the Institute on the Technical Committee of Motor Industries. Sir Hugh Bell and Sir Charles Allen represented the Institute on the Board of Scientific Societies of the Royal Society. Dr. Arthur Cooper was appointed to represent the Institute on the Council of the Engineering Training Organisation. Sir Robert Hadfield had been re-elected as representative of the Institute on the Court of Sheffield University, Mr. W. Peter Rylands served in the same capacity on the Court of Liverpool University, and Mr. W. R. Lysaght, C.B.E., on the Court of the University of Bristol.

GRANTS TO OTHER ASSOCIATIONS.

As reported last year, the council voted a sum of 500*l.* as a grant to the British Engineering Standards Association (Engineering Standards Committee) for the purpose of assisting the association to increase its activities in foreign countries. The grant was payable in three yearly instalments, the second of which, amounting to 166*l.*, was paid during 1918.

After referring to various alterations in the membership of the council, the report gave the names of 169 members of the Institute on service in the forces of the Allied Nations. This total does not include the names of two members of the Institute staff, one of whom, Mr. Arthur Dowd, Rifleman, K.R.R.C., died at Havre on February 9 last.

BESSEMER MEDAL.

Owing to the enforced absence in the United States of the nominee for the Bessemer medal this year, Professor Cav. Federico Giolitti, Turin, the award was postponed.

The chairman then presented to Mr. Auguste Greiner, who was present on behalf of his brother, Mr. Léon Greiner, a replica Bessemer medal, stating that it was just six years ago since the original medal was handed to his father, the late Dr. Greiner, in recognition of his eminent achievements in the metallurgy of iron and steel. In the following year, Dr. Greiner honoured the Institute by accepting the presidency. No one at that time foresaw the calamity which was destined so soon to overtake Belgium, and it was well known to all members how the city of Liége and the great undertaking, with which Dr. Greiner was associated so long, were overwhelmed after a truly heroic resistance. The members also knew how Dr. Greiner bravely faced the storm, encouraging others by his own indomitable courage, and carrying on the direction of the works in the face of unheard-of oppression and difficulties; how, finally, he succumbed under the burden of his heavy responsibilities and died a victim of the war and of his devotion to duty. It became known later that he was forcibly removed for a time from his residence and was treated as a common prisoner; his chateau was, in the meantime, occupied by officers of the invading army. On Dr. Greiner's return he found that various objects of value, among them his Bessemer medal, had disappeared, appropriated without doubt, or one might frankly say stolen by some officer of the ex-Kaiser, a practice which Mr. Greiner and he (the chairman) had good reason to know was afterwards largely extended wherever the invaders set foot.

The council, therefore, determined as soon as ever conditions permitted, to present a replica of the medal to Mr. Léon Greiner, son and worthy successor of Dr. Greiner. The new medal differed from the original in one respect only, in that it bore a brief inscription engraved around the edge recording the history of the former one, and reading: "Replica of the medal stolen by the Germans during their unjust occupation of Liége, 1914–1918."

The chairman then said: "Mr. Greiner, in the name of the Institute, I now present to you this copy of the former medal, in memory of your noble father, Dr. Adolphe Greiner. We beg you to accept it with our sincerest good wishes, and trust that you may long be preserved to carry on the direction of the establishment which he ruled for over a generation."

Mr. Auguste Greiner thanked the meeting for the posthumous honour to his father, and expressed the regret of his brother, Mr. Léon Greiner, who could not be present at the meeting, owing to the visit of the King of the Belgians to the Cockerill works.

The meeting then commenced the reading and discussion of the papers on the list; we shall deal with the further proceedings in our next issue.

(To be continued.)

INDUSTRIAL ADMINISTRATION.—There is to-day a widespread desire for instruction in the principles and methods necessary to the efficient administration of industrial enterprises. The responsibility for executive control is largely vested in the engineer, and he is recognising the advantage of scientific training for those duties. Here and there the universities are making some headway towards meeting the pressing need in this direction, but a very great deal remains to be done. Certainly in London there is far too little being done, and we therefore welcome the more heartily the private enterprise of Mr. Edward T. Elbourne, as announced in our advertisement columns, in arranging to give a summer course of lectures in Factory Organisation, Labour Administration and Factory Accounting. Mr. Elbourne's book on Factory Administration and Accounts is so widely known and appreciated in the engineering trades that we anticipate he will meet with the success he deserves. We note with interest that opportunity will be given for discussion at the end of each lecture, and we see in that provision a desire on the part of the lecturer to avoid dogmatic treatment and a willingness to face practical issues.

THE LATE MR. G. M. APSEY, R.C.N.C.

By the death of Mr. G. M. Apsey, which occurred at Sanderstead on Saturday, May 3, the Admiralty lost one of its most faithful servants, and the Royal Corps of Naval Constructors one of its best known and valued officers. Mr. Apsey came of a Sheerness family, and was a nephew of the late Mr. Henry Morgan, for many years Chief Constructor at the Admiralty, and he leaves a brother in Mr. John Apsey, C.B.E., Manager of the Constructive Department of H.M. Dockyard at Portsmouth.

Entering Sheerness Dockyard by competition in 1877, Mr. Apsey made good progress, and gained a place in the competition for entry into the Royal Naval College, Greenwich, as a Student of Naval Construction, in 1882. He continued to make good progress at College, and took a better place on the list each year, passing out with a very good second-class certificate and being appointed an Assistant Constructor of the Third Class at H.M. Dockyard, Chatham, in July, 1885. His entry at Greenwich was contemporaneous with several notable men, including Engineer Vice-Admiral Sir G. G. Goodwin, K.C.B., Engineer-in-Chief; Mr. W. J. Luke, shipyard manager of Messrs. John Brown and Co., Clydebank; Mr. Lewis Nixon, the American shipbuilder, and a Russian student, who as Colonel Techernigovsky, became head of the design branch of the Russian Admiralty. Others of the same entry are Mr. W. D. Archer, the Principal Ship Surveyor of the Board of Trade, and Mr. J. H. Narbeth, Assistant Director of Naval Construction, Admiralty.

Mr. Apsey was promoted to the rank of Second-Class Assistant Constructor in 1891, and First-Class in 1898. He served at the Admiralty from March, 1894, to February, 1895, when he became an Inspecting Officer for Torpedo-boat Destroyers, and in this capacity did excellent work, until November, 1902, when he was appointed to the Department of the Director of Naval Construction, Admiralty, serving under the Superintendent of Contract Work. He was transferred to the Dockyard Department in August, 1913, and promoted to Chief Constructor, Gibraltar, on December 1, of that year. In the summer of 1915 he was transferred to the new dockyard at Rosyth, and served there until June, 1916, when he was transferred to Portsmouth yard to assist the manager of that important establishment. He only remained at the southern port one month, and joined the Department of the Director of Dockyards at the Admiralty in July, 1916. During his services at Rosyth he found the climate very trying after the two years at Gibraltar. During the winter of 1915 he suffered a very severe attack of pneumonia, which left him quite a different man, and he never fully regained his former strength. After an illness of several weeks he became somewhat suddenly worse on Monday, April 28, and gradually subsided, passing away peacefully on Saturday, May 3, in his fifty-sixth year.

Mr. Apsey was a fine type of man, absolutely straightforward and without guile, and although there may be nothing notable outstanding to his credit in the development of naval construction, his career was marked throughout by faithful, intelligent service. He was a man of great tact and good judgment, and was able to maintain the Admiralty standpoint consistently with the preservation of the intimate friendship of all contractors and officials with whom he came into contact.

THE X-RAY EXAMINATION OF METALS.

*Researches into the Industrial X-Ray Examination of Metals at the Laboratories of Messrs. Schneider, Le Creusot.**

By E. SCHNEIDER.

IT is not the object of this paper to describe the radio-metallographic installation used in the laboratories of Messrs. Schneider's Works, nor to explain the working of the apparatus. The apparatus used is the standard type plant manufactured by Messrs. H. Pilon, who are the licensees for the Coolidge tube in France.

The normal working current used is 4 milli-amperes with a spark gap of 25 cm. (10 in.), corresponding to a difference of potential at the terminals of about 120,000 volts.

Every precaution has been taken to protect the operator from the X-rays and secondary radiation.

The apparatus under discussion permits of the penetration of 40 mm. of steel. It is easily transported and may be installed in a workshop for the purpose of examining samples on the spot.

RESULTS OBTAINED.

The following is a summary of the results obtained since the plant was installed:—

(a) Researches into segregation and blowholes. Influence of aluminium on cast steel.

(b) Examination of steels containing different percentages of tungsten.

(c) Examination of compound metals.

(a) The first application which suggests itself is an investigation into the heterogeneity of material (microscopic heterogeneity, of course). The diffusion of the X-rays, the consequent formation of secondary rays, and the grain size of the emulsion of the photographic plate limits the size of particle detectable to a diameter of not less than $\frac{1}{4}$ mm.

This method was first of all applied to the investigation of blowholes in cast steel. Steel plates (railway fish-plates 23 mm. thick) were cast in sand moulds without any special precaution being taken. The results are shown on the present page.

In the photographs each white spot represents a blow-hole. Figs. 1A and 2A show the sections (actual size) of these plates along the lines A B and A^1 B^1. (The black circles are the holes in the fishplates, which were plugged up with lead whilst the exposure was being made, to prevent the formation of secondary rays on the photographic plate and its consequent fogging.† Surrounding these circles will be seen radial spots which correspond to blowholes normal to the walls of the holes. This was checked by splitting a plate in the region of a hole.)

The two fishplates exhibit very different forms of blowholes. In fishplate No. 1 (Figs. 1 and 1A) they are near the surface and stretch out in a direction perpendicular to the walls of the mould. In No. 2 (Figs. 2 and 2A) the blowholes are central and very large in volume.

Figs. 3 and 4 are radiographs of fishplates made at the same time as fishplate No. 2, with steel from the same cast, in moulds made from the same sand and dried under the same conditions. But at the moment of casting the plates, 37·5 grammes of aluminium for each kilogramme of steel was added in the case of fishplate No. 3;

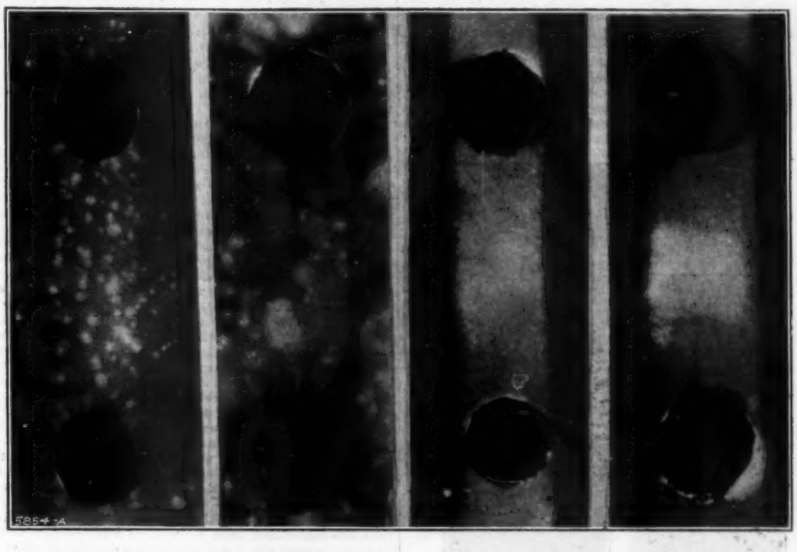


FIG. 1.—Radiograph of Fish Plate No. 1. Time of Exposure: 3 Mins. 30 Secs. 4 Milli-Amperes. AB, Line along which the Fish Plate was Split (Plate 1a). Holes Blocked up by Lead.

FIG. 2.—Radiograph of Fish Plate No. 2. Time of Exposure: 3 Mins. 30 Secs. 4 Milli-Amperes.

FIG. 3.—Radiograph of Fish Plate No. 3 obtained by adding 37 parts in 100,000 of Aluminium at the Moment of Casting. Time of Exposure: 3½ Mins. 4 Milli-Amperes.

FIG. 4.—Radiograph of Fish Plate No. 4 obtained by adding 75 parts in 100,000 of Aluminium at the Moment of Casting. Time of Exposure: 3½ Mins. 4 Milli-Amperes.

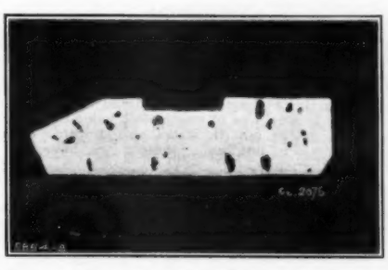


FIG. 1a.—Photograph of Section through AB of Fish Plate No. 1.

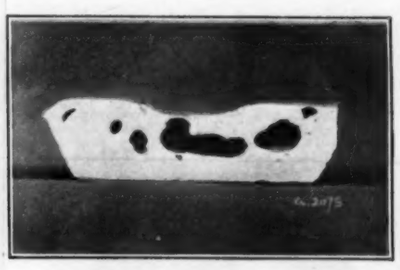
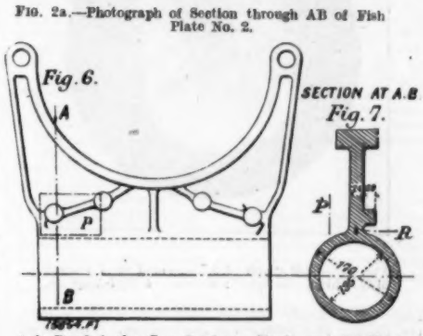


FIG. 2a.—Photograph of Section through AB of Fish Plate No. 2.

FIG. 5.—Blow-hole. Time of Exposure: 3 Mins. 4 Milli-Amperes. (The Position of the Rib on the Radiograph is Slightly Modified by the X-rays having been Projected Conically).



Axle Bracket of a Gun Carriage. Equipment 155 M/M., Long-Recoil Schneider Type.

Figs. 3 and 4 are radiographs of fishplates made at the same time as fishplate No. 2, with steel from the same cast, in moulds made from the same sand and dried under the same conditions. But at the moment of casting the plates, 37·5 grammes of aluminium for each kilogramme of steel was added in the case of fishplate No. 3;

* A contribution to a general discussion on the Examination of Materials by X-Rays, held jointly by the Faraday Society and the Röntgen Society, on Tuesday, April 29, 1919.

† It is for this very reason that the samples to be radiographed are surrounded by lead, either by inserting the sample in a sheet of lead or by casting the metal round the sample. In certain cases fine lead shot can be used, this being retained in place by suitable means. Round about the sample radiographed in Fig. 10 will be seen the limits of the fine lead grains thus arranged.

and 75 grammes per 100 kg. weight of steel in the case of No. 4.

The two photographs (Figs. 3 and 4) show the diminution in the number and size of the blowholes when the quantity of aluminium added on casting is increased, and also shows clearly the action of this metal in deoxidising the molten steel. By radiographing test pieces containing increasing quantities of aluminium it should thus be possible to determine, for a given casting, the minimum quantity of aluminium to be added to eliminate central blowholes.

Fig. 5 is a radiograph of a cast steel bracket of a gun wagon forming part of a 155-mm. calibre long-recoil gun equipment. Figs. 6 and 7 show the bracket diagrammatically, No. 7 being a section. Fig. 5 is a radiograph of the portion bounded by the plate P. On the radiograph, the black parts correspond to the rib. The white spot is a clearly defined blowhole which comprises the solidity and strength of the bracket. This blowhole was due to defective casting. By changing the method of casting, brackets were obtained in which this blowhole was not present.

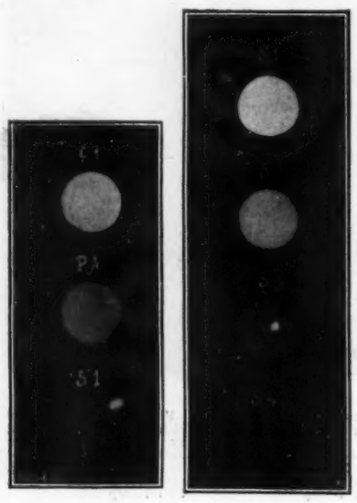


FIG. 8.—Radiograph of Plates 5 M/M. thick of Steels, C_1 with 1.15 per cent. C; P_A with 5 per cent. W; S_1 with 10-11 per cent. W. Time of Exposure: 5 Secs. 4 Milli-Amperes.

FIG. 9.—Radiograph of Plates 5 M/M. thick of Steels, S_1 with 10 per cent. W; S_2 with 14 per cent. W; S_3 with 18 per cent. W; S_4 with 22 per cent. W. Time of Exposure: 60 Secs. 4 Milli-Amperes.

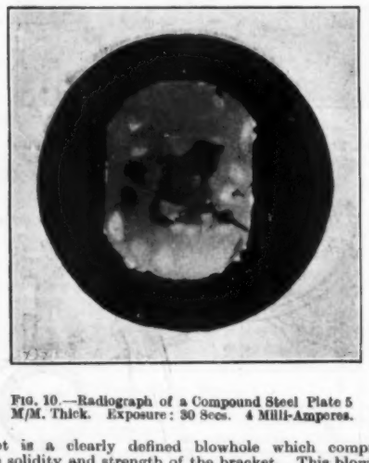


FIG. 10.—Radiograph of a Compound Steel Plate 5 M/M. Thick. Exposure: 30 Secs. 4 Milli-Amperes.

Application.—When a steel casting is made and it is desired to ascertain whether blowholes form in the metal when cold, a small piece of extra metal about 20 mm. to 30 mm. thick is cast in one with the main casting, this extra piece being examined under the X-rays.

When a new casting is being made in which, owing to the method of casting adopted, there is reason to suspect the existence of a defect at a particular point, this particular part is radiographed to ascertain whether the metal is sound. This may lead to a change being made in the method of casting.

Unfortunately there are limitations to this method owing to the lack of penetration of the X-rays. It is not possible to penetrate a thickness of more than 45 mm. of ordinary steel, and even for this thickness the time of exposure is considerable.

(*b*) Plates 8 and 9 are radiographs of plates of the same thickness (5 mm.) of steels having different compositions, as follows:—

C_1 steel containing 1·15 per cent. carbon.
P_A steel containing 5 per cent. tungsten.
S_1 steel containing 10 per cent. to 11 per cent. tungsten.
S_2 steel containing 14 per cent. to 15 per cent. tungsten.
S_3 steel containing 18 per cent. to 19 per cent. tungsten.
S_4 steel containing 22 per cent. to 23 per cent. tungsten.

When the percentage of tungsten (which is of high atomic weight, viz., 182) is high, the plates are not so permeable to the X-rays as when this percentage is low.

When suitable illumination is employed these differences show up much more clearly on the negatives than on the positives. Thus three carbon steels, containing 0·6 per cent., 0·9 per cent. and 1·15 per cent. of carbon respectively give a radiograph in which are clearly observable the differences in opacity corresponding to these percentages. We have not been able to make from this negative a satisfactory positive on which the different degrees of opacity may be clearly distinguished.

It would appear possible, then, to apply radiography for the purpose of a rapid analysis in particular cases. If, for instance, carbon steel bars have been mixed up inadvertently with tungsten steel bars, they could be sorted out speedily by radiography, instead of a chemical analysis being necessary, which is always a long, delicate and expensive operation. The following might be the *modus operandi* in this case. Bars of unknown composition and a bar of the standard steel of the same thickness would be laid on a slab. A radiograph would then be taken and the opacity associated with each bar measured. The values obtained, compared against a chart drawn up from steels of known composition, would permit of a deduction of the nature of the various bars.

(*c*) A sample of compound metal has also been examined. Fig. 10 shows that this metal is formed of a central bar and of small bars of the same nature embedded in a different metal. The centre bar and the small bars contain a constituent of lower atomic weight than the mass (analysis showed that it was chromium). The shapeless black spots at the centre and in two of the small bars are associated with a metal of high atomic weight. This latter was the tin of the bath in which the bar had been annealed and which had penetrated into the interstices of the metal.

(*d*) The method has also been applied to the examination of an ingot of a light aluminium alloy, 110 mm. in diameter. The radiograph enabled the ingot to be sawn through, without error, at the end of the blowhole, which was clearly shown in the photograph.

CONCLUSIONS.

In the present state of our knowledge of X-rays and their production, the application of radiometallography enables a visual examination to be made of ordinary steels provided their thickness does not exceed 40 mm. to 45 mm. This limiting thickness is reduced when the steel contains at least one constituent of higher atomic weight. It would be of inestimable value in metallurgy if ingots of 20 cm. thickness and upwards could be radiographed; but unfortunately we have not yet reached that stage.

Still, every step in the direction of finding a director more sensitive to the X-rays than those that we already know (photographic plate, barium platino-cyanide screen, ionisation phenomena) will lead to progress in radiometallography. Similarly, as the means of producing X-rays of high penetrative power are improved, it will be possible to increase the scope of X-rays in the examination of metals.

THE SOCIETY OF ENGINEERS (INCORPORATED).—In compliance with a suggestion by the Ministry of Labour, Appointments Department, the library and reading room of the Society of Engineers (Incorporated), 17, Victoria-street, Westminster, S.W. 1, have been placed at the disposal of officers at present looking out for appointments in the engineering and allied professions.

MARINE SURVEYORS' ASSOCIATION.—An association of consulting marine engineers and surveyors and superintendent engineers is at present being formed. Meetings have already been held at London and at several of the principal ports. A meeting was held at the Station Hotel, Newcastle-on-Tyne, on Monday, May 5, 1919, and there was a large attendance of surveyors from Tyne, Sunderland, Hartlepool and Tees district. A resolution to the effect that the formation of the association be proceeded with was unanimously carried.

THE INNS OF COURT REGIMENTAL ASSOCIATION.—The task of finding employment for ex-officers is of first importance. With the revival of industry which is now taking place, opportunities should be many, and, for the fully-qualified men, the problem depends for its solution on the provision of an efficient medium by means of which employers can get in touch with candidates of the requisite qualifications. The Inns of Court Regimental Association, which has a large register of ex-officers, provides such a medium, and employers and others, who have vacancies or openings for men of the officer type should notify to this association their requirements. The association has already been successful in placing many of its members in appointments ranging from mere clerical posts to partnerships and directorships where capital is brought in. No fees are charged, and the increasing co-operation which is now being obtained by it from employers is, no doubt, due to the personal methods which it employs, and its capacity for fitting the right man for the opportunity. Communications should be sent to the Secretary, Inns of Court Regimental Association, 10, Stone Buildings, Lincoln's Inn, London, W.C. 2.

RADIOTELEGRAPHY AND THE SOLAR ECLIPSE.

Radiotelegraphic Investigations in Connection with the Solar Eclipse of May 29, 1919.

IN connection with the forthcoming solar eclipse on May 29, 1919, the British Association Committee for Radiotelegraphic Investigation (of which Sir Oliver Lodge is the chairman) have arranged for the carrying out of some experiments on the effect of the eclipse on signals transmitted across the zone. The following descriptions of these experiments may be of general interest.

The umbra intersects the earth's surface in an approximate circle of diameter about 234 km. (126 sea miles), and it moves at the slowest at a speed of about 0·57 km. (0·31 sea mile) per second. Between 11·30 and 12 noon (Greenwich mean time) it travels across Bolivia and Brazil, and it crosses the Atlantic close to the equator between 12 noon and 14·20. It then crosses the African Continent from the French Congo to Mozambique. During the eclipse various wireless telegraph stations will emit signals consisting of letters of the alphabet changed according to a definite plan at the end of each minute; the programme of letters is so arranged that no two come together in the same order more than once. They will be accurately timed at selected receiving stations. By this arrangement the transmitting stations are relieved of the responsibility of timing the signals accurately, and the receiving operators have nothing to do but to write down each letter as they receive it and the number denoting its strength on the scale (0 to 9) familiar to all wireless telegraphists. On the day before the eclipse the stations will send practice signals for a short time near noon (Greenwich mean time).

The British Admiralty stations at Ascension and the Azores will send continuously during the transit of the umbra across the Atlantic Ocean. Observing stations north of the equator will for the most part be asked to listen to Ascension for at least an hour round about the time when the umbra passes between themselves and Ascension. Similarly observers south of the equator will be asked for the most part to listen to the Azores. Certain selected stations north of the equator will be asked to listen to the Azores so as to afford check observations upon the variations that may be observed in signals passing across the central line of the eclipse, and similarly selected stations south of the central line will be asked to listen to Ascension. The great American station at Annapolis will also transmit a programme during a portion of the period of the eclipse, and it is hoped that arrangements may be made for special experiments between a few pairs of stations, such as Darien and the Falkland Islands, and an Egyptian station and a South African station.

The main portion of the experiment hinges upon Ascension. The umbral cone passes from west to east, and may be expected to affect in succession the strength in which signals are received at such stations as Demerara, Jamaica, the stations on the coast of the United States and Canada, stations in Ireland, England, France, Italy, in the Mediterranean and in Egypt.

It is by the kindness of the American Government and of our own Admiralty that the stations at Darien and Annapolis and at Ascension and the Azores are being used for the sending of the experimental waves. The Admiralty has besides provided many of the receiving stations both on land and sea, and other receiving stations are being put to work by the American, French and Italian Governments, by our own Army and Air Force, and also by the Marconi Company, in several parts of the globe.

The observers' results will be collated with a view to finding if the passage of the shadow cone between a sending and a receiving station causes any regular change in the strength of signals. According to some writers the propagation of waves over long distances is greatly affected by the ionisation of the upper atmosphere. During a solar eclipse the cone of densest shadow removes all sunlight from the atmosphere within it, which may stop the ionising actions exerted by sunlight and allow the recombination of separated ions to take place. This process starts in the penumbra, but it is accomplished fully—or to its fullest extent—only in the umbra. Thus at any particular fixed place in the air the penumbra, it is thought, first starts gentle recombination of ions, and as the eclipse at the place progresses and darkness increases, recombination of ions takes place more and more quickly till the time of complete totality. Afterwards the onward passage of the umbral cone allows sunlight to begin again its ionising action. Something of this kind is at any rate supposed to be taking place at sunset and sunrise every day and to be the main cause of the enormous variations experienced in signal strengths at those times. It is sometimes supposed that the electric waves carrying signals take a curved trajectory in the atmosphere from one point to another. In this case signals passing between two stations at a short distance apart will traverse lower levels of the atmosphere than those passing between stations separated by a great distance.

The eclipse probably affects the ionisation of the upper layers and lower layers of the atmosphere differently, and therefore we may expect to get different effects on long and short range signals. Moreover, it has been shown to be probable that long waves are more affected than short waves by changes of the ionisation of the air through which they travel. The elucidation of this point is one of the aims of the observations.

Anyone desirous of obtaining further information should communicate with Mr. W. Eccles, Honorary Secretary of the Committee, City and Guilds Technical College, Leonard-street, London, E.C. 2.

THE MECHANICAL PROPERTIES OF STEEL.

*The Mechanical Properties of Steel, with Some Consideration of the Question of Brittleness.**

By W. H. HATFIELD, D.Met., of the Brown-Firth Research Laboratory, Sheffield, Associate Member.

ULTIMATE success in ensuring the safety of parts constructed of steel is dependent upon a sympathetic collaboration of the engineer and the metallurgist. A perusal of recent publications leaves the definite impression in one's mind that at the present moment engineering design has hardly attained the position in which it can be considered as a subject for purely mathematical treatment. We have much to learn, not only concerning the distribution of stress in the different parts under working conditions, but also of the actual mechanical and physical properties of the steels when in the diverse conditions under which those various parts are called upon to perform their duties. The author hopes in this paper to extend somewhat the data at present available in this direction. In a recent paper, Dr. Rosenhain, F.R.S., and Mr. Hanson† made the following statement: "For this purpose an impact test has been used, for, although it is recognised that conditions under which failure occurs in boiler plate possess no apparent resemblance to those of an impact test, yet experience has shown that materials which give a low figure under an impact test are liable to fail under apparently static conditions." It will be seen that the authors quoted seek to determine the safety of a part under static conditions by the employment of a dynamic test.

One can, however, fully appreciate the question at issue in their minds, and it is hoped that this paper may throw a little light on such matters. Another recent statement, in this instance, by Dr. Arnold, F.R.S.,‡ has a bearing upon the subject under consideration. He states: "In fact, no matter how dangerously brittle steel may be from chemical or physical causes, if such causes have co-produced a high elastic limit, the Wöhler test indicates the steel to be quite safe if stressed well short of that limit, when, as a matter of fact, it is inevitable that the steel must certainly rupture soon or later under stress theoretically quite safe." The author's reply to Dr. Arnold would be that any theoretical conclusions of the type to which he is referring must be based upon insufficient data. If a part is not stressed beyond its elastic range it must necessarily successfully withstand the stresses upon which it has to deal. It is considered that Professor Unwin, F.R.S., adequately deals§ with the subject in the following words: "All the published experiments on endurance tests have now been brought together and reduced to common measure, because the subject of safe limits of stress, especially in bridges, must, before long, be reconsidered, and because, while experiments of this kind take a long time to make, it is the number and the consistency of the results which are most impressive. A few results of bars breaking with comparatively small stress may be put aside as possibly accidental or abnormal, but here are four completely independent series of researches by different observers (Wöhler, Sir Benjamin Baker, Bauschinger and Spangenberg) with stresses of different kinds on very different materials, and the whole of the results are singularly consistent. In all cases the number of repetitions of loading the bar will bear diminishes with increased range of variation of stress."

One might continue, with advantage, to quote Professor Unwin's summing up of the data extant at the time at which he wrote, but those interested may refer to the original at their leisure. The author has always considered Professor Unwin's reply as an adequate commentary on such statements as those already quoted.

It is clear that there is a safety range of stress in which any given material may be stressed for an indefinite period. There is obviously a minimum range of stress which, over a long period, will produce rupture. However long this latter period may be, it is clear that whilst on more or less empirical calculations the stresses may have been shown not to exceed the elastic limit of the part under consideration, it is certain that some local piling up of stress must have taken place to produce rupture. If we now supplement the work to which Professor Unwin has referred with items from recent investigations, it is possible to obtain a more complete picture of what is happening. The work of Dr. Coker and others upon unequal stress distribution during recent years has done much to indicate the insufficiency of some of the empirical calculations upon which design has depended so much in the past.

The researches of Rosenhain and Ewing, and others, with regard to the development of slip-bands and the commencement of failure of crystalline metals, have done much to explain the effect of local accumulation of stress. It will be seen from these remarks that it is considered that, given reliable material, it should be possible, in the course of time, when our data are more complete, to so determine our factors of strength that the different parts of our various mechanisms may be perfectly reliable.

The engineer is familiar with the properties of steel, in the first place by actual experience with it in service, and in the second place by the results obtained from different mechanical tests to which such materials are put. The mechanical tests at present available may be recapitulated somewhat as follows. The static tests include tensile, torsion, bend, and Brinell. The dynamic tests include the Izod, Charpy and Frémont impact tests; the Stanton repeated-blow test, the Sankey, Arnold and Wöhler alternating-stress tests; the Shore scleroscope should also be included in this category. There are also the different wear tests, such as those devised by Dr. Stanton, Mr. Saniter, and others. There are other tests, but those just mentioned represent the ones which the author employs in his (different) investigatory work.

Later in this paper will be found instances of results obtained by the use of them, and in Appendix I will be found the size of test-bars employed, together with a statement of the detailed conditions, so that direct comparison may be made with similar tests performed by other investigators. The author would at this stage take the opportunity of emphasising to engineers the danger of crediting any particular types of test with predominating importance. In his opinion, the tensile test is fundamental, but all the other tests are valuable as bringing out in each case data not otherwise fully disclosed concerning the properties of the steel under examination.

The Investigation of Failures.—As regards failures in service, the author's experience is that there is frequently some obvious cause. Whether or not the cause is obvious it is, of course, existent. The fugitive nature of the explanations of some failures which he and others have experienced is the real reason for the presentation of this paper. Whilst discussing failures in service, it is well to point out that the explanation of failure is frequently assisted by examinations of examples which have done excellent service. Too little examination is made of the latter, and it is frequently the case that many features of failures are considered to be bad ones, which would most likely be cancelled out by the same features being discovered in excellent examples. When cases come to the Brown-Firth Research Laboratories for investigation, the following procedure is adopted. In the first place, the design of the part and its relation to other parts in the mechanism in which it serves, are carefully studied, together with the actual conditions of service, that is, the magnitude and manner of the stresses the part is called upon to withstand. In this preliminary investigation some idea is obtained as to the possible mechanical causes of failure. The manner in which said failures would be assisted by inherent undesirable characteristics in the steel is next investigated. The chemical composition is determined to indicate the quality of the steel; the microstructure is examined to determine the thermal treatment to which it has been submitted, and the macrostructure is developed with a view to determining the homogeneity of the mass. The mechanical tests, including an adequate selection of the previously enumerated ones, are performed. For purposes of comparison a companion examination of a successful part is put through wherever possible.

As a result of numerous investigations, failures seem to place themselves in different categories. Treating the matter broadly, there are two types. In the first one, failures would be included where the material has rightly been assumed by the engineer to possess strength and freedom from defects, but when the material unfortunately did not merit his confidence, that is, the material has failed to live up to reasonable expectations. In the second category, would be placed the wide range of cases where subsequent examination has shown the material reasonably to possess properties which the engineer associated with it, but where failure has obviously been due to insufficient knowledge or to too empirical treatment on the part of the engineer with regard to the stresses with which he had to deal.

In the first category one would include cases where the steel is put to work in the wrong condition; where it has received faulty heat-treatment; where it has been put to work in an unstable condition; and lastly, where the part has been placed into service containing undiscovered actual defects. In the second category one must include bad design; imperfections of the technique and production; abnormal stressing (shock, deformation leading to overstressing, &c.); an imperfect knowledge of the full properties of the steel by the engineer; and lastly, an imperfect knowledge of the distribution of stress in the parts under consideration.

Fatigue failures, so called, may come under either category, that is, the steel may be well below the requirements in strength, or the part may be too weakly designed to withstand the repetition of stresses which has to be encountered. There are two further sources of failure which it is considered should also come under the second category, namely, wear and corrosion. The author recently investigated a very serious case where the failure of a shaft through corrosion would have been prevented, had the engineers responsible appreciated the more simple causes of corrosion. The question of wear is naturally a matter definitely within the field of the engineer, although the metallurgist must take some responsibility.

Different cases of past failure which have been thoroughly investigated are of considerable interest. At times also such cases are aggravating since, as years pass along, new methods of approach and means of testing are developed, from which, could they only be applied to some of the past cases, clear explanations might possibly be provided of important cases which are even now only improperly understood. Whenever possible, some of the material of such important failures should be retained so that in years to come some of it can be forthcoming to form the subject of subsidiary helpful investigations in the light of more recent knowledge. It is stated that the Greeks raised an altar "to the unknown God"; it is our practice always to retain a suitable piece of steel for submission to that new and at present unknown test, which it is hoped will some day be devised, capable of giving information which at present is absent from our tests. A few of the types of failure at present under discussion may be quoted.

Some little while ago the author read with considerable interest a paper by Mr. Sidney Houghton* on "Certain Failures of Steel Boiler Plates under Pressure." Mr. Houghton surveys and discusses a number of cases of failure, and apparently comes to the conclusion that we are yet without a satisfactory explanation of some of the most serious causes of failure in that field. The author has carefully followed many of the cases to which Mr. Houghton refers, and he is entirely of the same opinion. In the discussion of this paper Dr. Stead, F.R.S., described a very interesting case of a boiler-plate burst under pressure. It was found that there were many hundreds of fine hair lines running from the rivet holes, yet curiously there were many good features about the plate. The analysis would be considered satisfactory, but the carbon was as low as 0·09 per cent. The maximum stress was 24 tons, the elongation 30·7 per cent., whilst the reduction of area was 64 per cent. Dr. Stead stated that, in his opinion, the yield was probably about 12 tons. It is recorded that the microstructure was good, and that the non-metallic inclusions were not pronounced. One very interesting feature of Dr. Stead's investigation was the alternating-bend test to which he submitted some of this material. A value of 733 reversals before fracture was obtained, which was quite good when compared with the value he states for good English plates, namely, 760 to 970. This alternating-bend test, coupled with other considerations, would certainly point to the material being by no means in a brittle condition. Dr. Stead was not dogmatic in his conclusion as to the cause of failure in this instance, but was inclined to think that the cracks were produced by the maltreatment of the material in the vicinity of the rivet holes. It is of interest to record that he thinks that the low yield may probably have assisted failure by fatigue. This is a well authenticated case of failure carefully investigated by a recognised authority, and is certainly most instructive. It is hoped to refer to it later. The actual manner of the distribution of the stresses in the vicinity of the rivet holes is of considerable importance, and has been tackled by several investigators, notably Dr. Wolff. The design and technique of the riveting will always have a profound influence, and no doubt many of the failures in boiler plates might be rightly traced in that direction.

In a recent paper previously referred to, Rosenhain and Hanson describe an investigation into the cause of cracking in a thick boiler plate. The failure examined occurred in the last stage of manufacture, that is, cracking during cold bending. The authors present interesting data and the results of subsidiary experiments bearing upon the case. They deduce that the cause of failure lay in the growth of large crystals in the ferritic bands, claiming such crystalline growth to be responsible for the low impact value of the material, and that the low impact value of the material was an indication of the mechanical properties which produced failure. The processes through which this particular plate had passed were those through which other plates had passed which had not cracked, and the author's conclusions would have been more convincing if they had definitely shown that successful plates had not possessed the same features which they condemned in the plate which had failed. One would rather suspect that the breakage of this plate was due to the presence of mechanical defects or the production of small incipient flaws by over-bending in the cold. Unfortunately, the stages of bending are not published. The author discusses this paper now, since it has a direct bearing upon the technical points which he hopes to bring forward later.

Another well-investigated failure is that of the St. Neots rail. This failure was the subject of a Board of Trade Inquiry. It has also been dealt with by Dr. Arnold, F.R.S., Dr. Stead, F.R.S., and others. Here we have an extremely valuable instance of a failure with many well authenticated details. The rail was 22 years old, and it had worn down $\frac{1}{4}$-in. under traffic abrasion; it then subsequently smashed into a number of pieces, causing the well-known disaster. One eminent investigator states that thousands of rails of worse composition had served satisfactorily. The mechanical properties, as shown by the tensile tests, were good. One extremely important feature, however, seems to be that the upper surface of the rail consisted in many parts of a martensitic layer (layer of hardened steel). This layer contained thousands of hair cracks. Such a martensitic layer may conceivably have been produced by abnormal effect of the brakes, and such a layer would yield the minute cracks just described under subsequent usage. The main points that it is wished to record are:—

1. The original satisfactory condition of the rail as proved by the satisfactory behaviour over 22 years.
2. Its mechanical condition.
3. The presence of surface cracks.

Leaving this case for the present, it is proposed to describe an interesting case which recently came to the author for investigation. He was informed of a case in which a piece of structural steel (angle-iron) made from shell discard, had broken sharply in two with a blow from a 14-lb. hammer. The fracture is illustrated in Fig. 1, page 616. He was incidentally informed that this occurrence had raised grave doubts in the minds of the firm concerned with regard to the advisability of the extended use of such material. In due course the pieces came into his hands, and an investigation was entered into with considerable enthusiasm, as here indeed was apparently an instance of really brittle steel. In the first place the chemical composition of the material was determined, and it was immediately found that the steel was not shell discard, but low-carbon structural steel. That discovery, in itself, as will be appreciated, was quite an important one when present circumstances

* Paper read before the Institution of Mechanical Engineers, on Friday, May 2, 1919.

† Journal of the Iron and Steel Institute, vol. i, 1918.

‡ Inst. of Naval Architects, 1908.

§ "The Testing of Materials of Construction," page 355, 1899 Ed.

* West of Scotland Iron and Steel Institute, 1918.

are considered. The figures obtained in the analysis were as follows:—

	Per Cent.
Carbon	0·09
Manganese	0·65
Silicon	0·017
Sulphur	0·038
Phosphorus	0·061
Tungsten	Nil.
Chromium	Nil.
Nickel	Nil.
Vanadium	Nil.
Titanium	Nil.

Microsections were prepared and the microstructure of the steel studied. In Fig. 2 will be found a photograph of the unetched structure which gives an idea of the amount of non-metallic inclusions present. There is, of course, always more or less of this non-metallic matter in these structural steels, and its lay-out is always parallel to the direction of rolling; hence in this particular instance the inclusions were in a path at right angles to the fracture. In Fig. 3 will be found the etched structure at 100 diameters and the amount of pearlite, together with the size of crystal, can be studied. In Fig. 4 will be found the microstructure of the material at 500 diameters, and this particular photomicrograph enables the condition of the pearlite to be examined. The author did not consider that the micro-examination brought out anything abnormal, but found that it confirmed the results of analysis.

The mechanical properties of the material were next studied in proximity to the fracture. The tensile values, including the elastic limit (limit of proportionality) were determined, and then the different values were obtained under the Arnold, Charpy Izod, Frémont, Sankey, and Stanton tests. The hardness was determined by both the Brinell and Shore methods; the results will be found in the following table, whilst the full details of the actual tests will be found in Appendix I:—

Tensile—	
Elastic limit	15·9
Yield-point	20·9
Maximum stress	29·4
Elongation of area	30·0
Reduction of area	61·9
Alternating Impact, &c.—	
Arnold alternating-stress test	211 reversals.
Charpy impact test	2·9 kgm. or 20 ft.-lb.
Izod	50 ft.-lb.
Frémont	23 kgm. 90 deg.
Sankey Alternating-bend test	33 bends 2,320 ft.-lb.
Stanton repeated-blow test	635
Hardness—	
Brinell hardness number ...	120
Shore Scleroscope number ...	20·5

It is considered that these values are of much interest. In the first place, the Arnold and Sankey tests give too good values for the steel to be considered brittle. The Charpy, Izod, and Frémont give values which must be considered very good, therefore the steel is not brittle under the notched-bar tests. For 28 tons to 32 tons steel the tensile values must be considered quite satisfactory. Why, therefore, should this angle-iron of good composition, microstructure, and mechanical tests break with a single blow from a 14-lb. hammer? The explanation appeared to be forthcoming as a result of a careful examination of the fracture. At the point marked by the arrow there was a discolouration indicating a sharp, already existing crack of small area. The author considers that this crack led to an undue concentration of stress, and that, in spite of the good qualities of the material, fracture extended right through the piece in the manner described. Continued observations, both in this country and abroad, have readily and finally established that the sharpness of a notch or the gradually decreasing value of the radius at the bottom of the notch, accentuates its effect in reducing the amount of energy absorbed in destroying an impact test-piece. It is now firmly established that the stresses become increasingly great locally to a notch according to its sharpness. Professor Hopkinson, in one of his papers* has observed quite truly that if the bottom of the notch or crack were infinitely sharp, this concentration of stress would cause the production by a small force of a high local stress at the base of a notch or crack sufficient to exceed the strength of the material and cause a continued propagation and development of fracture. In other words, failure such as occurred in this piece of structural steel, in some of the cases of boiler plate failures and, in the author's opinion, in the St. Neots rail, have been due to existing cracks of considerable "sharpness," which have, by their creation of unduly high local stress, exaggerated abnormally the work which the material was locally called upon to do. Impact values may vary considerably in a given steel, but a high impact steel as already shown, is not impervious to disastrous failure under conditions such as those just discussed.

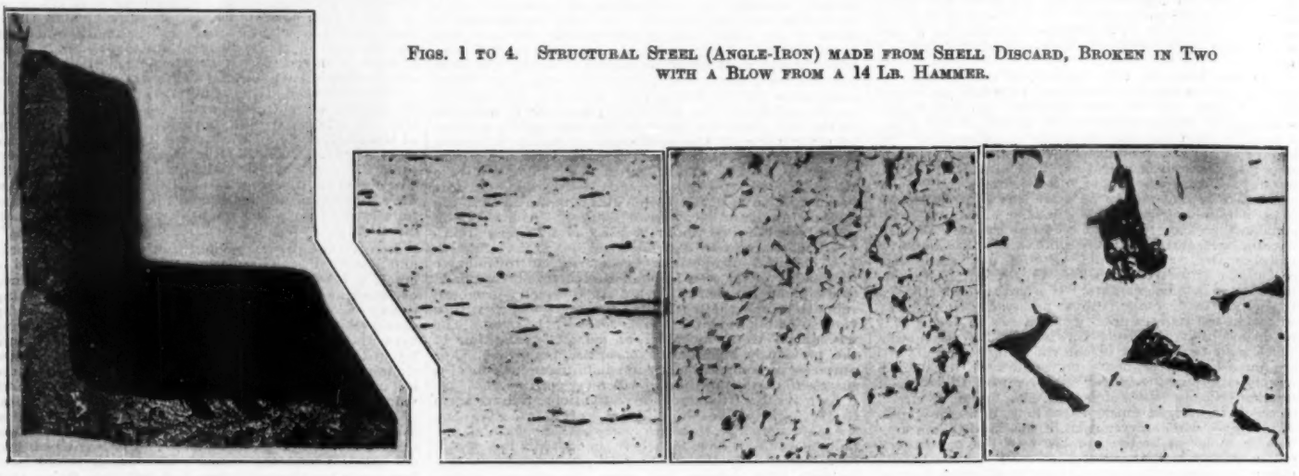
It will be noted in the case of this piece of structural steel just described that the Stanton value is low. In a 60-tons tensile steel values of 6,000 to 8,000 blows are obtained. In this particular instance the energy of blow was exactly the same, and the low value is explained by the low elastic limit. It will be observed that this low value (Stanton) was obtained in spite of a high notched-test value. The general argument for the utility of the notched impact (single-blow) test usually relies on the claim that through inadvertence or design, sharp corners, notches, defects, even cracks have to be counted under actual service conditions.

Surveying notched-bar, impact and "fatigue" tests generally, the author considers that one definite fact is apparent, namely, fatigue tests with notches, such as the Stanton test, do not show any relationship to the impact values. For instance, two high-tension steels of a suitable elastic limit otherwise identical, one giving 50 ft.-lb. under the Izod, whilst another gives 8 ft.-lb., will be found not to show any disparity under the Stanton test, both breaking under that form of test at something like 7,000 blows. As an instance of actual observations made, the diagram shown in Fig. 5 is instructive. There will be found the results of tests on six 60 tons to 65 tons steels. The full tensile values, together with the Stanton, Izod and Charpy values were obtained. It is clear that everything else being equal, the incipient cracking prior to rupture of the material occurring at the notch of the Stanton test-piece should, on the above argument, have been prevented from developing by the high impact value of the material, thus providing a discrimination. To the author's mind it would appear that the inference to be drawn from this and other data which will be provided later, is that once the elastic range has been passed, final rupture cannot be prevented by variations in impact value. Hence arises the fundamental importance of thoroughly considering the distribution of stress and the providing of a sufficient factor of safety in relation to elastic range.

A Discussion of the Methods Employed for Mechanical Testing.—As regards the tests now in use for the mechanical testing of steels and irons, it may be safely said that each provides information of value. This may be stated without excepting any individual test. How are we to judge the relative value of the diverse means of testing from the engineers' point of view? It would appear that those tests are most instructive concerning the ultimate behaviour of the steel, which nearest approximate to, or reproduce, the conditions under which the steel has to serve. The tensile and torsion tests are of particular value, and in most cases clearly give a direct indication as to the suitability of the material. Particularly useful for purposes of design is a more complete knowledge of the elastic range under these two forms of test. Until more ready means of determining the limit of proportionality in the tensile test than the present-day extensometer can be obtained, such determinations cannot become routine tests, but the engineer might usefully obtain sufficient number of such readings to assist him in more accurately calculating his safe ranges of stress.

As regards the tensile test we have much to learn, and investigations such as those which have of late been pursued by Professor Dalby, F.R.S., are invaluable. He and other workers have advantageously shown the value of the detailed study of even our most commonly employed tests.

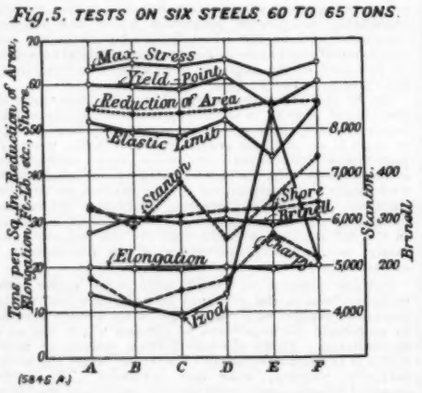
As regards impact testing, much work has been done during recent years, and we are now fairly equipped with data presenting the responses made to such tests by steels when in diverse conditions. We have now to face the difficulty of interpreting and making use of such values. Before being able to do so, we must correlate them and reconcile certain existing anomalies. An invaluable paper was given before this Institution some time ago by Harbord.* His main deduction appeared to be that it was extremely difficult to reconcile and correlate the different values obtained from such tests. In some measures the difficulties still exist. The Izod and Charpy tests have now been thoroughly standardised, and with few exceptions the values obtained are consistent; furthermore, they have a general relationship which illustrates the influence of variations in the form of notch. One interesting feature of this relationship is typical, and at first sight requires much consideration. The Charpy test is much less discriminating in cases of notched-bar "brittleness" on low impact value material, the energy required to break the piece per square cm. being less by the Izod than by the Charpy method, whilst with high impact material the energy absorbed per cm.² is greater at times with the Izod than with the Charpy notch. Although it is not unusual for impact values to be translated into terms per sq. cm., such conversion is not safe since the depth behind the notch has a fundamental influence upon the value of the reading. Thus the effect of the "V" notch of the Izod test-piece, when compared with the round notch of the Charpy test-piece, is completely obscured in some notch tough conditions by the effect of the reduced section in the Charpy test-piece. Extremely valuable experiments of Schule and Brunner† have shown that the decrease in depth of the material behind the notch very substantially reduced the energy absorbed per sq. cm. of cross-section. Thus, were the sectional



FIGS. 1 TO 4. STRUCTURAL STEEL (ANGLE-IRON) MADE FROM SHELL DISCARD, BROKEN IN TWO WITH A BLOW FROM A 14 LB. HAMMER.

FIG. 1. FRACTURE. FIG. 2. UNETCHED. × 100 DIAM. FIG. 3. × 100 DIAM. ETCHED. FIG. 4. × 500 DIAM.

Fig. 5. TESTS ON SIX STEELS 60 TO 65 TONS.



* Sheffield Society of Engineers and Metallurgists, 1908.

* Proceedings, I.Mech.E., 1908, page 921.

† International Association for Testing Materials, 1909.

area of the Charpy test-piece the same as the Izod test-piece, the former would, by actual experiments, give in cases such as those under discussion much the higher values of energy absorbed. Here is one typical instance illustrating how difficult it is to compare the results of one form of impact test with another.

As regards the Charpy and Frémont tests, the values seem to be of a similar order, but anomalous cases occur from time to time which are extremely difficult to explain. The Arnold and Sankey tests would appear to indicate and give a measure of the same specific properties of the material, and incidentally the values obtained by these two tests indicate variation of a similar order. Yet the values obtained from either of these tests have no relationship to the values brought out under static or notched-bar impact test. That, however, is no reason why they should be dismissed as being without merit. In both tests the steel is severely punished by repeated alternate bending, each bend being accompanied by considerable plastic deformation. The wide variation in values obtained certainly point to indication being obtained of some intrinsic merit of the material.

In the author's opinion, the Stanton test or some modification of it, in which the force of the blow is capable of being varied with the elastic range of the steel, seems to be capable of offering much useful information to the engineer. This test is one which certainly does approximate to the conditions existing in some slightly over-stressed parts. The values obtained are influenced apparently chiefly by the magnitude of the elastic range, and are not much influenced by notched-bar brittleness; neither do they appear to be influenced by that property in the materials which are brought out in the Arnold and Sankey test. The elastic range is not, however, the only determining factor. In making these comments it is only fair to state that the author has hitherto only employed the standard conditions laid down for this test in the Appendix. In support of the Stanton method the whole of the experimental work of Wöhler draws us to the same conclusion. The author has much sympathy with the view expressed by Stanton and Bairstow,* when they say: "For determinations of resistance to shock under approximate working conditions, the test should be one in which the energy absorbed in plastic deformation is at a minimum, since plastic deformation has little relation to its constructional value." Single-blow impact tests do not afford sufficient information for the engineer, and the author feels that he has provided data in this paper sufficiently conclusive to indicate that such single-blow impact tests, depending as they do upon the energy absorbed in plastic deformation above the elastic limit, yield insufficient and probably no data as to the elastic range, and the behaviour of the material within that range.

There are no doubt concrete cases where each test will provide data of particular service in some field of engineering; and the careful study and selection of the tests to be employed in each field merits, and will repay the most careful attention of the engineer. This paper has dealt with the response of different steels to the more simple forms of test. An examination of the nature of the stresses acting on various parts of machines and structures will indicate that in many cases the stresses are not of a simple character, but are combinations of tension, compression, shear, &c. To the designer who wishes to create a reasonably safe design, and at the same time to economise and get the most out of the material employed, a knowledge of the behaviour of the material under these complex stresses is important. Much interesting work has been done in investigation of the effects of such stresses, notably by Guest, Hancock, Mason, Scoble, Smith and also by A. J. Becker, of the University of Illinois. The presence of a second stress at a given point in the material, in a direction at right angles to the first, modifies the response of the material to the first stress, as would be expected. To the author it appears that a complete experimental study of all the different combinations of stresses likely to be met with in practice carried out on all those materials of construction likely to be employed, would constitute a work of far-reaching value to engineers.

Impact Tests.—There are obviously many instances in which it is expedient that steel shall be stressed beyond its elastic limit, and, therefore, in such instances, some knowledge of the behaviour of the material under impact tests is generally considered instructive. Various types of tests have been devised, all with the purpose of measuring the relative brittleness of metals. They include impact-bending tests, impact-tensile, and impact-crushing tests. The author's remarks are intended to apply chiefly to those tests described in Appendix I. In all these impact tests the value obtained is essentially dependent upon the energy absorbed by the material in plastic deformation, and the experimental work by different investigators has generally been with a view to determining the factors which affect this absorption of energy. During recent years much progress has been made. For instance, it is now definitely established that the properties of the material as shown by the static tensile tests, that is, elastic limit, yield, ultimate stress, elongation and contraction of area, fail at times to reveal differences brought out under the notched-impact tests. It is generally established that, everything else being equal, the harder the material the smaller the energy required to produce rupture under the notched-impact tests. There are, however, instances where steels of the same hardness give widely different values under the impact test, and in some such instances the tensile test and, for that matter, the microscope, utterly fail to give any indication of the difference in the material. It is in this respect that the Izod, Charpy, and such impact tests give information of interest. Two pieces of the same steel may be hardened and tempered to have similar tensile properties, and yet have widely dissimilar properties under the notched-bar impact and notched-bar slow-bending tests. Much work has been done in this direction by a number of investigators, but a complete and valuable treatise on this subject was presented by Captain Philpot some months ago.* In this paper Philpot confirms the earlier excellent work of Stanton and Bairstow,† indicating that the shock in the test is not the determining factor, and shows that the type of notch is the essential. He records a number of interesting experiments in which notched bars are broken under a static load and such disparities in values as are obtained under the Izod notched-bar impact tests are equally well brought out when the load is slowly applied. His experiments also clearly indicated that up to, and for some considerable distance beyond, the range of proportionality, the behaviour of the two steels was identical. These facts are of fundamental importance to engineers.

The influence of the shape of the notch has been very thoroughly investigated, and it is clearly shown that with increasing sharpness of notch the discriminating value of the test is increased. As an instance of the comparative effect of the shape of the notch, it may be pointed out that the Charpy test with a ½ mm. radius, shows a much less disparity in the materials in unlike condition than does the Izod test; a reference to Fig. 5 (page 618), which contains the results of the Izod and Charpy tests, will confirm this.

It was long thought that the speed of application of, and the total energy of the blow had an influence upon the energy absorbed in breaking the test-piece. This has now been shown to be a mistaken view. There are several sets of experiments now in existence covering this point, and the author has published the result of investigation.‡ in which it is clearly shown that with Izod impact-pieces breaking with an absorption of 20 ft.-lb. to 25 ft. lb. energy, it is immaterial whether the blow be 150 ft.-lb. or 50 ft.-lb.

Other points have been taken up such as the effect of the temperature at which the test is carried out, and a bibliography is attached to this paper for those interested in the subject, Appendix II.

As regards repeated-impact tests, the total energy required to fracture the test-piece increases as the number of blows required increases. This is largely due to the fact that each blow includes a certain amount of energy necessary to produce the elastic deformation, and this proportion naturally forms the larger percentage of the energy of the blow when the blow is small in value. As to the actual energy absorbed in plastic deformation it is an open question as to how this value is affected with the reduction in the force of the blow. There appears to be in all repeated-impact tests a limiting value of blow which can be indefinitely withstood by the material.

The author is, however, only dealing with the impact test in so far as it is of interest as indicating dangerous brittleness in steels from the engineer's point of view. From this standpoint it might be useful to endeavour to trace the mechanism of the action of rupture in one of these tests. For this purpose it is proposed to discuss the Izod test. The actual pressure exerted by the knife-edge on the piece is determined by the amount of resistance which the piece offers to deformation. The resistance commences at zero and increases rapidly at first, presumably in proportion to the deviation of the piece from the vertical. This phase will only continue during elastic deformation (which is extremely small), owing to the piling up of the stress near the bottom of the notch, and the elastic limit of the material will be reached locally at a very early stage whilst the remainder of the test-piece will be almost unaffected. At this stage plastic deformation commences. In non-brittle materials it is to be anticipated that plastic deformation will then proceed, with the drawing out longitudinally and contraction of area of the steel close to the bottom of the notch taking place. The region affected plastically will gradually enlarge, the outlying portions being always less severly strained than the original base of the notch. In this way the deformation continues until the most drastically deformed portion has received the maximum drawing out of which it is capable, and then it will crack. The crack, once in existence, will rapidly spread. The base of it (when definitely formed) being sharper than any notch made by machining, causes such abnormal local stressing relative to the surrounding material, that the original crack always extends in preference to rupture commencing afresh at any other point. The back face of the test-piece (not notched) is all the time under compressive stresses, but owing to the more uniform distribution, the actual maximum compressive stress at any point, before permanent deformation occurs, is very small in comparison with the tensile stress at the notch. During the plastic deformation, however, this compressive stress increases, and it may reach such a value that locally there may be fracture by shearing, and an appreciable bulging similar to, but not so marked as, that of the ordinary bend-test. A slight modification of shape of section on the notched side, feebly imitating that in an ordinary bender, is to be expected. The form of fracture usually indicates whether an appreciable amount of plastic deformation has taken place at the fractured portion, previous to the progression of the crack. In brittle materials the "crack" appears to be first started at a very early stage of the plastic deformation. It may be suggested that the bulk of the energy absorbed in the test is that due to the work done on the test-piece, in plastic deformation previous to the commencement of the crack, very little being absorbed before this begins (elastic deformation), and very little after, that is, during the extension of the crack. The relative proportions of the three stages of work will obviously vary with different materials, or conditions of the same material. It would appear from this argument that a governing factor in determining the amount of energy absorbed in the test is the degree to which the material can be plastically deformed before the formation of a "crack." This would be expected to run parallel with the elongation per cent. of a tensile test-piece (or preferably with the reduction of area per cent.) and a low elastic. While this generalisation is in the main borne out by impact values, the agreement is only approximate and, as previously discussed, there are exceptions. It must, therefore, be concluded that failure as at a shoulder or the bottom of a notch, is determined not only by the degree of deformation but also by the manner of distribution of the stresses.

In the latter sections of this paper results of experimental work will be given in illustration of the diverse values obtained from different materials, and at this stage the author proposes to content himself by showing that even wrought-iron of the highest ductility is susceptible to variations in notched impact test values, the values under static test remaining practically constant. He was successful in obtaining a bar of excellent

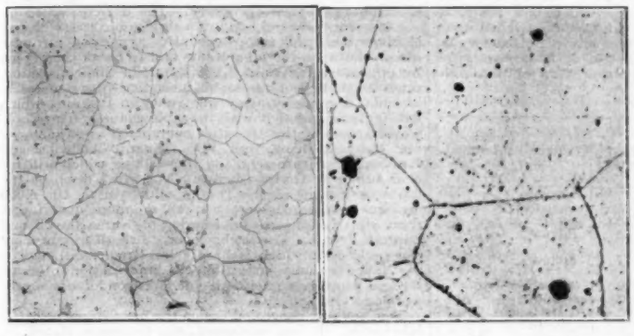


FIG. 6. WROUGHT IRON (AS RECEIVED).
× 100 DIAM. ETCHED. × 500 DIAM.

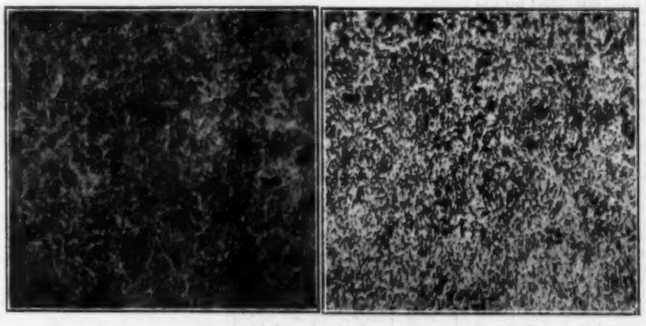


FIG. 7. BAD CONDITION NICKEL-CHROME STEEL.
× 100 DIAM. ETCHED. × 500 DIAM.

* Proceedings, I.Mech.E., 1908, page 889.

* Inst. Auto. Eng., 1918.

† Proceedings, I.Mech.E., 1908, page 902.

‡ Journal of the Iron and Steel Institute, 1917, vol. ii, page 112.

wrought-iron. In Fig. 6, page 619, will be found the microstructure of this material in the condition as received, at 100 diameters and 500 diameters respectively. It will be seen to consist entirely of iron crystals, the only other constituent being a little slag left in during the process of manufacture. Any slag present in the test-bars experimented upon ran the length of the bar, being striated at right angles to any blows received in impact testing. Chemical analysis curiously enough showed that this specimen of wrought-iron contained a little carbon, the value being somewhere between 0·05 per cent. and 0·08 per cent. As regards other constituents, the silicon was 0·03 per cent., manganese 0·08 per cent., sulphur 0·013 per cent., and the phosphorus 0·019 per cent. It will thus be seen that we have here an exceptionally pure commercial wrought-iron. Tensile, Izod impact, and Brinell determinations were done upon this material in different conditions, and the figures derived from determinations on a selection of the treatments are given in Table I.

These experiments establish that in a most ductile iron with an elongation of 40 per cent., and a reduction of area of over 60, the impact values may vary from over 70 down to nearly 20, without the values under the static test being seriously affected. These few tests have been selected from an investigation at present in progress, and the author does not propose to burden his paper with a metallurgical discussion of the results. Suffice it that here we definitely have curious anomalies from the metallurgical standpoint, but data sufficient to show that even the most ductile materials can be made susceptible to notch brittleness without their ductility having been destroyed. The micro-examination of impact test-pieces after deformation has already been published by the author.*

The question which has to be decided is whether we must dissociate notch brittleness from true brittleness, which must be admitted is occasionally experienced in steels; but the author proposes to defer his deductions until the concluding pages of this work. The problem to be solved is this: can, and will, really brittle steel give satisfactory results under static tests, or does it need a sharp notch to bring out the evidence of brittleness.

TABLE I.—TENSILE, IZOD IMPACT, AND BRINELL DETERMINATIONS ON WROUGHT-IRON. (Fig. 6, page 619.)

Condition.	Elastic Limit.	Yield-Point.	Maximum Stress.	Elongation.	Reduction of Area.	Fracture.	Izod Impact.	Fracture.	Brinell Hardness Numbers.
		tons per sq. in.	tons per sq. in.	per cent.	per cent.		ft.-lb.		
As received	8·5	9·26	18·93	40·0	64·71	Fibrous	62	Fibrous	67
Quenched from 300 deg. C.	—	6·74	17·09	43·0	64·71	Fibrous Silky	77	Fibrous	65
Quenched from 770 deg. C.	—	9·82	18·48	41·5	64·7	Fibrous	22	Coarsely crystalline	67
Quenched from 950 deg. C.	—	8·0	18·8	38·0	63·6	Fibrous	22	Coarsely crystalline	73
Quenched from 950 deg. C., tempered 650 deg., and air-cooled	—	9·36	18·52	44·0	64·71	Fibrous Silky	71	Fibrous	65

From a theoretical point of view, it is eminently desirable that we should form some idea as to the reason for variable values obtained from notched-bar tests, other values being constant. Captain Philpot in his paper, to which reference has already been made, suggested segregation between the crystals as the cause, but the author cannot accept that explanation, since he has difficulty in conceiving the segregation of material in terms of the size of crystals at a temperature at which such effects are known by metallurgists to be produced. If two pieces of suitable nickel-chrome are hardened and are then subsequently tempered, say at 600 deg. C., one being then quenched in water and the other being very slowly cooled, it will be found that the one which has been quenched from the tempering temperature in water will have a high impact value, whilst the one which is cooled slowly will have a low one. This is a statement which applies to many, though not all, steels, and which is now definitely accepted by metallurgists. It is the author's experience, and he knows it is also the experience of many others, that the microscope utterly fails even at the higher powers at present available, to bring out any adequate indication of differences in structure sufficient to account for the large difference in impact value. It therefore follows that it is reasonable to suppose the cause to be more deep-seated and probably lies in the ultra-microscopic arrangement of the material. It has occurred to the author that if the ultimate arrangement of the atoms could be visualised, it would be found that, on quenching from the tempering temperature, the material had been trapped in a—from a crystalline standpoint—meta-stable condition, that is, the atoms would not have had the opportunity of finally attaining their stable positions in the systems of the crystals. He would therefore suggest that if after the tempering has been done at temperatures such as that under discussion, and the cooling be permitted to take place at a slow rate, resulting in a low impact value, the atoms have had the necessary time and opportunity to take up their stable situations in the crystal.

He would then argue that the reason for the difference in the manner in which the crack is extended is to be found in the relative facility with which it can travel through the diversely orientated crystals. It appears to him to follow that in a perfect crystal, cleavage planes mill offer planes of weakness along which the crack way readily run, whilst in the unstable state, in which the perfection of the arrangement is not attained, he would submit that it is conceivable that the crack will not travel with the same ease. It will be seen that this line of reasoning would pre-suppose fracture through crystals in both ductile and "notch-brittle" material. This is contrary to the views held by some investigators, but the author, in all seriousness, considers that it yet remains to be demonstrated that fracture frequently takes place along the crystalline boundaries. For instance, he would argue in this way; a crystalline fracture leads one to suppose that there are a number of minute planes reflecting light. Since the crystals of the metal with which we are dealing have no external geometrical form, it is difficult to conceive how such externals of the crystals, if they were separated, could present facilities for the reflection of light in the manner which to him appears perfectly obvious from crystalline fractures. It might, therefore, be thought that he would suggest that the fibrous fracture associated with high impact values with its non-crystalline appearance, would represent the separation between the crystals; such, however, is not his view, since he holds that in the fibrous facture a sufficient explanation is found of the fact that in the transit of the crack through the crystal in this case, there is a good deal of deformation and distortion along the cleavage faces. Arguing back from the above to the region of fact, it will be remembered that we have a mass of evidence to show that most successful parts which have been submitted to the most stringent service, have had a low impact value. The inference which might be made from the foregoing is that the impact values induced by quenching from tempering temperature, involving as they do a meta-stable condition from a crystalline standpoint, also involve a crystalline instability which will probably be affected by the work which the parts are called upon to do under certain conditions of service. One fact is, however, obvious, namely, that if it is necessary to quench from tempering temperatures to obtain high impact values, internal stressing will accompany the result, and it is an open question whether, if for no other reason, it is not better to be satisfied with reasonable impact values produced by relatively slow cooling rather than endeavour to produce the other condition of the material.

A Truly Bad Condition.—Some time ago the author investigated the properties of a nickel-chrome forging which had been placed in a bad condition by an unsatisfactory final treatment. The intimation was that the Izod test-pieces in breaking absorbed no energy. The latter comment was somewhat exaggerated. However, the results of a detailed investigation into the mechanical properties are instructive. The figures obtained were as follows:—

Elastic limit	13·3 tons per square inch.
Yield-point	32·1 " "
Maximum stress ...	44·5 " "
Elongation	9·0 per cent.
Reduction of area ...	16·6 "
Izod	3 ft.-lb.
Charpy	0·31 kgm. (2·2 ft.-lb.).
Stanton	666 blows.
Brinell	210

It will be seen that the steel was in a really bad condition. The impact tests clearly showed brittleness, but this was also to be seen by the tensile in the low ductility. It may be stated that the tensile values were true ones, not being in any way affected by defects such as frequently reduce ductility. The true elastic limit was low as also was the Stanton result. The micrographs of this material are given in Fig. 7, page 619.

(To be continued.)

THE INSTITUTION OF CIVIL ENGINEERS.—At the meeting of the Institution of Civil Engineers, on Tuesday, April 29, there were elected as Honorary Members of the Institution, H.M. the King of Italy and H.R.H. the Prince of Wales. It was announced that the council had made the following awards for papers read and discussed at the meetings during the session 1918–19: A Telford gold medal to George Hughes (Horwich); a Telford gold medal and an Indian premium to R. B. Joyner, C.I.E. (Bombay); a Watt gold medal to W. S. Abell, M.Eng. (London); a George Stephenson gold medal to the Hon. R. C. Parsons, M.A. (London); a Webb prize to F. E. Gobey, O.B.E. (Horwich); Telford premiums to James Caldwell (London), and H. B. Sayers (London), J. Reney Smith (Liverpool), and F. W. Scott, M.E. (Benoni, Transvaal); and a Manby prize to E. L. Leeming, M.Sc.Tech. (Manchester).

* "Steels used in Aero Work," Aeronautical Society of Great Britain, 1917.

THE BELGIAN IRON AND STEEL INDUSTRY DURING THE GERMAN OCCUPATION IN THE GREAT WAR.*

By LEON GREINER (Seraing, Belgium).

IN July, 1914, Belgium was busily devoting herself to her commerce, her industries, and her agricultural pursuits, when suddenly, in the midst of her peaceful activities, came a thunderclap. There were reports of mobilisation; the assembling of arms; joy flies away and anxiety spreads on every countenance. War had broken out.

Hardly had she recovered from her stupefaction when our little country found herself invaded. The declaration of war had not, as yet, even been transmitted by Germany to France; an insolent ultimatum had barely, as yet, been received by our Sovereign, when our frontiers were violated by the foremost of the German cavalry.

On August 4 the forts around Liége were attacked. Their heroic defence lasted more than ten days. They were forced, nevertheless, to yield to the heavy calibre guns which the Germans hastily brought up, although history will record the decisive part which Liége played in the Great War.

Then came the advance, and, while the Allied armies held the Germans in check, there commenced that long period of four and a-half years during which our little country was occupied and cut off completely from its King, its Government and its soldiers.

The German Governor-General who planted his heavy jackboot on Belgium declared himself the representative of the Royal power. In that capacity he legislated, but solely in favour of the invader and utterly regardless of the rights of private property. The decrees issued by the Governor-General had but a single object: to despoil the land which his troops occupied, as masters; to sow discord between the inhabitants and to break their spirit by oppressive measures. I will not, in this connection, revert to the acts of barbarism, incendiarism and massacre of which the enemy army was guilty in Belgium, which will for ever brand it with indelible shame. The whole world knows of the atrocities committed in so many of our Belgian towns, and Vise, Dinant, Andenne and Louvain constitute so many bloodstains which will for ever adhere to German hands. Nor will I dwell on the innocent victims of the Teuton soldiery; on the 6,000 civilians whose massacre we can no more ever forget than you can the sordid murder of Nurse Cavell and Captain Fryatt. I wish, however, to recall to you more especially that which is hardly less tragic, although it has failed equally to strike the imagination of most foreign peoples, namely, the deportation of our work-people to Germany.

This act was concealed under the most hypocritical of falsehoods. It was necessary, the Governor stated, in the interests of the country itself to relieve charity of these useless and undesirable strikers. And thus it was that there came to be interpolated in the history of occupied Belgium this harrowing and most lamentable chapter of the deportation of these alleged "strikers," and of this reversion to the most cruel of the practices of barbarism—slavery. It is in this connection, too, however, that we are able to distinguish the truest sentiments of patriotism, of endurance, of voluntary and courageous sacrifice, even to death itself, of our Belgian workers, who would not work for the enemy. To relate the sufferings, the tortures of these unhappy people, would be almost impossible; even to enumerate the martyrology would take too long. The whole world was seized with horror at the accounts of the atrocities which were committed in the name of "charity" and in the "great moral interests of Belgium."

After the hard winter of 1916–17 we saw the return of such of these waifs of humanity as had been able to withstand this ill-treatment, and who, famished and utterly worn out, were flung back, without further ado, within the Belgian frontiers. How many of these 125,000 unhappy deportees died in Germany?

What the iron and steel industry of Belgium was before the war you all know; it was only necessary to traverse our little country to appreciate its importance. In 1913 the output of pig-iron reached 2,485,000 tons and the production of raw steel was 2,601,000 tons, while the output of finished products at rolling mills reached a total of 2,162,000 tons.

The invaders have passed over the land and with them their processes of devastation; of this flourishing industry nothing remains but the shadow. The factory chimneys stand out against a sky unclouded by smoke; buildings still stand huddled together with wide gaps between, but only the framework of industry survives, the soul has departed. Our works have been slain.

Blast furnaces, converters, open-hearth furnaces, rolling mills, machine tools, have, with very few exceptions, either been carried away or demolished or rendered incapable of resuming operations. How many months must elapse before we hear again the sounds of industrial life? How many years must pass before Belgium can resume her place amongst the big producers of iron and steel?

On August 1, 1914, our country possessed 60 blast furnaces, of which 49 were in blast; their total capacity approximated to 265,000 tons of pig-iron per month. On Armistice day there remained but four intact, representing 6·3 per cent. of the total productive capacity. Within a future which is uncertain, perhaps within a year, 25 others, amounting to 44 per cent. of the former capacity, may be put into a fit condition to be blown in. So much for the blast furnaces, the sources of all industrial activity in the iron and steel trades.

Most of the rolling mills have been destroyed by

* Paper read before the Iron and Steel Institute on Thursday, May 8th, 1919.

dynamite. Many of the blowing-engines have suffered the same fate. At the works of the Cockerill Company nine rolling mills have disappeared by these means out of 11, and only three blowing-engines remain out of 12. The same conditions obtain at the works of Ougree-Marihaye and at La Providence, and even more desolate are La Louvière Works, which belonged to the big owner Pol Boel.

Taking it all together, the havoc in the great iron and steel works (taking into consideration only those works which possessed blast-furnaces) is estimated at a purely approximate sum of 210,000,000 fr. This amount, based on prices as they existed in 1914, is only the bare cost of the plant destroyed, without taking into consideration any indirect expenses of any kind.

This, then, is the situation. The problems to be solved are numerous: the starting up of the few which have the good fortune to remain; the re-arrangement and restoration of the works. So much for the technical aspects. Side by side with these is the important financial question. Will it not be necessary to sink capital in plant, the cost of which is three times higher now than it was in 1914? How shall we be able, later on, to struggle against competitors whose capital commitments are three times less to discharge, or who have been able almost completely to write off the cost of their plant out of the profits they have made during the war? And when industry is re-established, shall not we, who depend on our export trade, find the world's markets occupied by the industries which have developed considerably abroad during the war?

All these problems are grave; the task before Belgium is vague, and we shall not be able to fulfil it without the help of those who, allied with us in the armed struggle, will, I doubt not, be side by side with us in the peace struggle for world-trade, and on whose assistance we must count in the difficult times our industries must yet surmount, after having undergone the harsh German yoke.

What has taken place during these four and a half years of occupation? At the beginning transactions in commerce and operations at works remained perfectly free. For this reason some of the works profited by this period to use up their raw materials and to convert them, for the general benefit of the country, into products of direct utility. Patriotic enthusiasm was intact and unanimous; the moral resistance to the plots of the invader remained invincible, both amongst the work-people themselves and the leaders of industry. To the stupefaction of the earlier weeks succeeded a period of waiting, a confident waiting for the help of our allies and for the triumph of justice. The conditions of material existence, the food conditions chiefly, were not insupportable, the privations and restrictions imposed by necessity were resolutely undergone; the whole Belgian people were opposed to the invader, but—it was still possible to breathe.

The industrial output of the country during 1915 was, nevertheless, extremely low. The production of iron was 68,150 tons, that of steel 110,180 tons, and finished rolled products 164,370 tons, which will be seen to be pretty reduced proportions, being only 2·75 per cent. of the pre-war pig-iron output, and 4·22 per cent. of the pre-war steel production.

Towards 1916 the Belgian rolling-mills began to use a considerable proportion of crop ends, and the production of the iron and steel works can be given as follows:—

	Tons.
Pig iron	127,825
Steel	137,590
Rolled products	223,335

or 5·14 per cent. of the pre-war pig-iron production and 5·29 per cent. of the pre-war steel production. But, under what conditions was work carried on? The chief difficulty lay in the scarcity of certain raw materials, and chiefly of manganese. At the Cockerill Works the Germans divided our stock of rich manganese ore into two portions—560 tons which they carried off, and 60 tons which they generously left us. How they were deceived? It was not 60 tons but 1,150 tons that we were able to hide from them, at the risk of our liberty, and to transform secretly, partly into spiegel, in the blast-furnace, and partly into ferro-manganese, in the electric furnace. On the other hand, the scarcity of coal for the producers compelled us, as shown by the note on the subject sent by your late President, Mr. Adolphe Greiner, to the May Meeting 1915, to attempt and subsequently to develop the utilisation of pitch as a fuel for the open-hearth furnaces. Special furnaces were constructed with this object, which allowed of our making open-hearth steel of most varied qualities, from sheets for brewery and sugar works vats to tramway sleepers.

The stocks of manganese ore were not, however, inexhaustible, and the war was protracted beyond anything that could have been foreseen. From the end of 1915 and in order to preserve the last few tons of ore for the manufacture of ferro-manganese, we succeeded in recovering the manganese contained in the material found in heaps on the slag tip, slags derived from old acid Bessemer converters. The average analyses of these slags, of which 15,500 tons were recovered by hand picking, was as follows:—

	Per cent.
Iron (about)	10·00
Manganese	10·00
Lime	1·50
Silica	55·00

This was the ray of light by which we were enabled to keep things going a bit; the recovery of the manganese by increasingly efficient means allowed of our manufacturing in the only blast-furnace in activity, and starting with this apparently intractable material: basic pig-iron containing 1·5 per cent. of manganese; then open hearth pig with 4 per cent. of manganese; then spiegels of varied composition ranging up to 16 per cent. of manganese, and finally, rich spiegel containing up to 30 per cent. of manganese. The latter, whose manufacture involved a burden consisting only of acid slag, lime, and coke (giving rise to a production of 10 tons of slag per ton of coke) was practically free from phosphorus, and replaced ferro-manganese.

Later on this special pig-iron became scarce and had to be economised; tests were made in order to replace a portion of the manganese additions by carbide of calcium made in our electric furnace. These experiments taught us that with a little care it was possible considerably to reduce the manganese additions, in fact we succeeded in working during a campaign of a fortnight by only using 3·25 kilo. of metallic manganese per ton of ingots made in the Bessemer converters, besides a little aluminium which was added in the moulds.

Still later, when only the open-hearth furnace was being used—and for a sadly reduced output—and the ferro-silicon had been exhausted, the electric furnace was able, similarly, to undertake the manufacture of this alloy.

We had the satisfaction of using up our very considerable stocks, and in addition large amounts of other materials that it was necessary to save from being requisitioned, namely 1,000 tons of rolls, 650 tons of ingot moulds, and 1,450 tons of special steels for springs, the barrels of rifles, nickel and chrome steels and other finished products, of the existence of which the Germans knew nothing, were thus sacrificed.

In the end, however, everything was lacking; raw materials, fuel, refractories, good luck no longer sufficed; the working shifts became ever shorter and fewer, and finally all activity in our works died down. It was then that the systematic destruction of our plant reached its full development.

The destruction of the Belgian works, under the form of requisitions, was the object of a regular organisation on the part of Germany. Both civilians and the military applied themselves zealously thereto, according to a well-established plan, and special departments were created with this object. Two leading organisations shared in the too facile task: Die Materialbeschaffungstelle and Die Maschinenbeschaffungstelle. The requisition was always based on the terms of one or other of the decrees (there were so many of them!) published by the German Military Government. The military officials of the different organisations promenaded the works to take note of whatever might suit their purposes. The Materialbeschaffungstelle undertook the search for material required directly at the front and supplies intended for military works in the occupied regions. It was this organisation likewise that, by means of the "Rohstoffverwaltung," carried off the high-speed steel for tools and copper of every description. It is needless to dwell on the sordid struggle, the rivalry in cunning, and on the specious conflict which took place between this organised thieving and its victims (who comprised everyone from the largest commercial undertakings down to the smallest individual) each time a decree authorising requisitions was promulgated. Each Belgian, it may be said, sought to preserve, from what was actually no more nor no less than robbery, all or part of the copper in his possession; it may even be added that many succeeded in deceiving their spoilers. How many others, however, had to pay for such attempts by many months' imprisonment?

The Maschinenbeschaffungstelle was only the instrument of a powerful limited company, the Wumba, in Berlin (Waffen und Munitions Beschaffungs Amt), a civil association directly under the control of the Ministry of War. It was to the Wumba that the German works addressed their requests for materials (tools, machines, buildings, overhead travelling cranes, &c.); with the Wumba that they discussed prices; and to the Wumba that they paid for their "purchases." We have seen the directors of large works—colleagues before the war—parading our workshops and steelworks, making their selections as though at a sale, measuring things up calmly and even arguing amongst themselves as to the possession of such and such a machine, just as they would have done had the material really been at their disposition.

The Wumba was the commercial undertaking for which the Maschinenbeschaffungstelle was the supply branch. It was the latter organisation which supplied information as to the existence of our works, which sought for machines corresponding with the specifications as transmitted from Berlin, and which, once the matter was agreed upon, made out the form of requisition and proceeded to the sequestration of the material. It was, needless to say, well organised. It was often a curious and heartrending spectacle to see the way the Germans proceeded with the demolition and despatch of machinery. Much of our more delicate machinery was already spoiled in the process before ever the trucks upon which they were carelessly thrown, without even a tarpaulin over them, had left the despoiled works, and how many will ever be returned even in fair condition, to say nothing of their being usable? And what a difficult task it will be to recover many of these machines, which their provisional proprietors, resorting to the devices of common "receivers," will probably have "camouflaged" carefully and beyond recognition. To assign a value to the requisitions of this organisation would be difficult. From the commencement it was more particularly machine tools which were its objects. It is said that 60,000 such machines were stolen from Belgium. But if the engineering workshops were the most especially and severely victimised by the Maschinenbeschaffungstelle, the ironworks were not overlooked: cranes, shears, all kinds of appliances, engines of all kinds, were removed under its orders, and are, even now, actually being used in the enemy country.

The Germans attempted at the commencement to adopt the method of immediate payment of these requisitions; the refusal to enter into negotiations or to lend a hand to any industrial operations whatever was as unanimous as the refusal to work friendly, and later on even the authorities ceased to endeavour to carry this out. The formula was in many cases extremely attractive—for the buyer; payment of the invoiced price, with a deduction of 10 per cent. in the value per year of service for the depreciation of machinery, to the credit of an account lodged in Germany. It may be asked whether, in the case of an old machine of more than ten years' service being carried off, we should have had to pay a certain percentage, in recognition of the "service" which was being rendered to us by relieving us of machinery which, despite its age, was still capable of giving valuable service.

An important victim of the Maschinenbeschaffungstelle was the new blast furnace gas electro-generative group of 10,000 indicated horse-power which the Cockerill Company was about to put in operation in its large central power-house at the moment when war was declared.

On December 1, 1917, and quite suddenly, a Commission, partly civil and partly military, came to take possession of the engines, access to which was forbidden to the staff of the works itself. The dismantling was commenced by an inexperienced gang, who endeavoured to remove the immense collector of the continuous current dynamo blade by blade by means of chisels and of wrenches. Later on a German engineering specialist presided over the work, which lasted for twenty months.

After the motor it was the turn of two overhead travelling cranes of 40 tons capacity, and the hall of 35-m. span which had been specially built to shelter the largest gas engine in the world. The technical difficulties which had to be surmounted were not little, the driving-shaft with its cranks and armature cross-head alone weighing no less than 130 tons.

The whole of these appliances are actually in course of being set up at the Kraft Ironworks (Abteilung Niederrheinische Huette at Duisburg). I say advisedly in course of being set up, for although the Armistice has been signed for the past six months, it would appear that the work is with strange inconsistency still continuing.

The German demolishers put the period of their stay in our works to profit. They used the interior of the huge columns and the girders of the overhead cranes as hiding-places for supplies of the most varying description, introduced into Germany by fraud and stolen from goodness only knows where—ham, brawn, antimony, lead, butter, bottles of wine, copper and high-speed steel, keeping one another company behind the shelter of the steel plates, which were carefully riveted up afresh after the introduction of their compromising contents. A single girder from a workshop 30 m. in height, and intended for the hardening of big guns, had concealed in its interior 700 bottles of wine and 1,000 kilos. of white metal. The demolitions in Belgium were thus serving a double purpose. Every one in the industrial world knows by now of the crimes committed by these systematic organisation for destruction and of the means employed to secure raw materials for the works beyond the Rhine; the savage and complete destruction of our works will long remain in our memories, and many visitors to our ravaged country have been able to see our blast furnaces ransacked and demolished; our powerful motors reduced to fragments, nothing remaining of them but their shorn and twisted foundation bolts; our workshops destroyed; our rolling-mills, with only their sites remaining, covered with a chaotic collection of debris, a mass of twisted scrap and demolished machinery. When it is remembered that this work of destruction was carried out by metallurgists like ourselves, executed coldly under the orders of engineers and professors of universities who knew, better perhaps than anyone else, the destruction they were accomplishing, when we contemplate these accumulated ruins, despite our constant and continuous experience during those fifty-one long months of warfare, one feels stupefied at beholding this magnificent testimonial to German "Kultur." The facts demonstrate conclusively that if the recovery of raw material was the avowed object of the organisation this object was none the less often only a pretext. Why should the most vital parts of our plant have been selected for destruction? Why should not, for instance, a single plant have been destroyed entirely for the recovery of the maximum of its materials instead of simply being mutilated and stripped of whatever was easiest to remove? Why undertake the work of devastation throughout every corner of the works simultaneously? Why were the thousands of tons of loose machinery, stores of scrap, not only distributed over the whole country but found in the works themselves, spared in favour of reducing to scrap motors and power-houses, blowing-engines and rolling-mills, the demolition of which was ten times as costly and difficult, or the destruction of a blast-furnace or a reheating furnace whose frameworks represent but an insignificant proportion of material and valea as compared with the cost of the furnace itself?

It is therefore perfectly certain that one of the chief objects pursued was to suppress future embarrassing competition, to disable for a long period to come a rival whose energy was dreaded, and to create a market for German enterprise which the Germans imagined they would be allowed to occupy after the war.

I have little more to add; we have now happily emerged from this nightmare, disabled and injured in the struggle, but hopeful and proud of the victory. We have nothing to blush for before the rest of Europe. At the cost of great sacrifice we have shown ourselves worthy of our great Allies, and we await, like them, that era of peace, of fruitful labour and of closer communion which may lead to the recovery of our prosperous past.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

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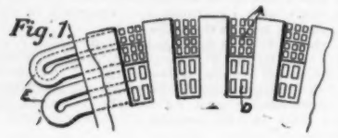
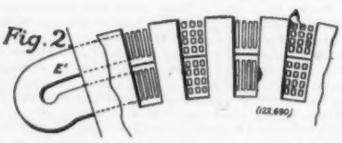
ELECTRICAL APPARATUS.

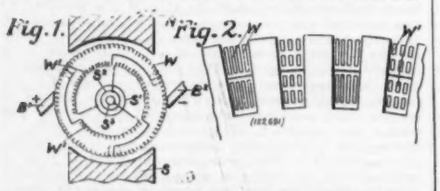
122,690. Submersible and J-L Motors, Limited, Southall, and H. K. Whitehorn, Southall. Dynamo-Electric Machines. (2 *Figs.*) January 28, 1918.—This invention relates to rotary transformers of the kind in which separate windings are provided on a drum armature. According to this invention, in a rotary transformer of the kind specified, the conductors of the separate armature windings are placed in different slots in the armature core. In rotary transformers of the kind specified as hitherto constructed as shown in Fig. 1, the direct-current conductors D and the alternating-current conductors A were placed in the same slots, the direct-current conductors being suitably connected together and to a commutator, and the alternating-current conductors being connected together and to slip rings. Referring to Fig. 2, one arrangement





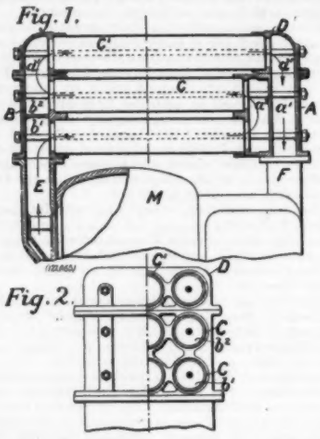
according to the present invention is shown, the direct-current conductors D and the alternating-current conductors A being arranged in alternate slots. By the method of arranging the conductors according to this invention a better space factor in the slots is obtained than with the arrangement hitherto adopted. Further, there are only half the number of coils to insulate, and the evolute parts of the conductors are more open and therefore not so difficult to form. The evolute parts of the conductors are shown projected at E in Fig. 1, and at E1 in Fig. 2. Owing to the improved form of the evolutes better cooling by ventilation is obtained. Further, a looser coupling between the separate windings is obtained than with the arrangement hitherto adopted, and consequently there is less liability to hunt or surge. (*Sealed.*)

122,691. Submersible and J-L Motors, Limited, Southall, and H. K. Whitehorn, Southall. Dynamo-Electric Machines. (2 *Figs.*) January 28, 1918.—This invention relates to dynamo-electric machines arranged to transform direct into alternating current or *vice versa*, of the kind comprising an armature with a main winding thereon connected to commutator segments, taps on this winding being connected to slip rings through auxiliary windings on the core of the armature. According to this invention, the conductors of the main winding are placed in different slots in the armature core from those in which the conductors of the auxiliary windings are placed. Referring to Fig 1, the poles of the field structure of the machine are represented by N and S, the direct-current brushes by B1 and B2, and the alternating-current slip rings by S1, S2 and S3. Taps on the winding W are connected to the slip rings



S1, S2 and S3 through armature windings W1. The provision of the auxiliary windings W1 permits of the machine to be designed to give any desired ratio to the voltages. By suitably arranging the windings W1 and choosing the correct tapping position on winding W, the windings W1 serve to boost up the voltage supplied to the slip rings. The windings W1 may obviously be arranged to lower the voltage supplied to the slip rings if required. According to the present invention, the conductors of the winding W are placed in different slots from those in which the windings W1 are placed. According to the design of the machine, the windings W and W1 may be placed in alternate slots as shown in Fig. 2, or there may be a less number of slots provided for the conductors of the windings W1 than for those of the winding W. The slots for the windings W1 may be smaller than the slots for the winding W. (*Sealed.*)

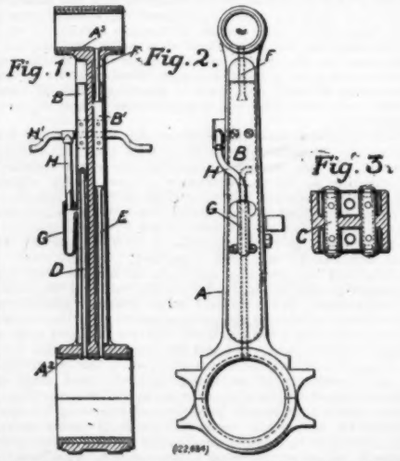
122,665. Electromotors, Limited, Openshaw, Manchester, B. Longbottom, Alderley Edge, and E. Greenhalgh, Rusholme, Manchester. Dynamo Electric Machines. (2 *Figs.*) November 2, 1917.—This invention relates to dynamo-electric machinery of the enclosed type, in which the enclosed air is circulated and cooled. According to the invention, the air passage-ways and end boxes of the several main elements are so arranged that the connecting openings and jointing facings therefor on the upper side of an element are in vertical alignment with the openings and jointing facings on the underside of the same element. Each main element comprises two end boxes; the box A is shaped so as to form the common return passage-way a^1, and a single inter-connecting chamber a^2, and the box B is shaped to form two inter-connecting chambers b^1 and b^2, separated by a diaphragm. Each box has two tiers of oppositely-located sockets to house the respective ends of the tubular parts C, which form the longitudinal parts of the air passage-way. The box A has two jointing facings which are respectively adapted to fit the jointing facing of the outlet E or the inlet F formed on the casing of the motor M; and the box B has two similar jointing facings, one on the chamber b^1 and one on the chamber b^2; in the arrangement illustrated one of the facings of the box A makes joint with a motor inlet facing, and one of the facings of the box B makes joint with a motor outlet facing, but the facings are made to a standard shape and distance apart, so that the boxes may be reversed end for end, relatively to the motor, and so that the facings on the respective boxes, when the latter are connected by the tubular members so as to form a main element,



fit the corresponding facings on similar elements located above or below them. The top element consists of two similar boxes D, having connecting chamber d^1 provided with facings corresponding with the facings of the boxes A and B, and, like the latter boxes, the boxes D have sockets to take a tubular part C^1. In the drawings, a single main element and a top element are assembled, and the path of the circulating air is: From the motor outlet E through the chamber b^1, tubular part C, chamber a^2, tubular part C, chambers b^2 and d^1, tubular part C^1, chamber d^1 and return passage-way a^1, to the motor inlet F, and thence through the motor casing to the outlet E. A main element, or several main elements exactly similar to the one shown, may be interposed between the one shown and the top element, and that being so interposed would provide two, or multiples of two, additional longitudinal parts of the zig-zag. In this way the same pattern of motor may be fitted with the desired number of elements necessary for any given rating. (*Accepted February* 12, 1919.)

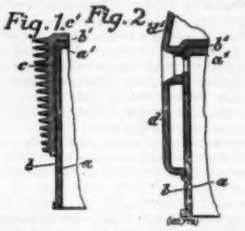
GAS ENGINES, PRODUCERS, AND HOLDERS, &c.

122,684. O. L. L. Brook, Coventry. Internal-Combustion Engines. (4 *Figs.*) January 25, 1918.—This invention relates to the lubrication of connecting rod bearings of internal-combustion engines. Situated in the channelled recess of the connecting rod A are chambers B, B1, which constitute the oil reservoirs. The reservoirs are secured to the connecting rod and to each other by pins C (Fig. 3), which extend through them and the web of the connecting rod A. The pins C are drilled with axial holes and transverse holes which intersect the axial holes to form oil conduits, which connect the interiors of the reservoirs B, B1. From the crank-bearing A2, a pipe D con-



stituting the oil supply pipe extends into the reservoir B. The lower end D3 of the pipe D is preferably so situated as to register at each revolution of the crank with the orifice of the main oil supply conduit in the crank-pin. In the reservoir B1, a pipe E extends from the crank-bearing A2. A pipe F also extends into the reservoir B1 from the crosshead-pin bearing A3. Attached to the wall of the reservoir B is a chamber G, the interior of which communicates with the reserpoir B. From the chamber G is led a conduit H provided with lateral branches H1, whose outlet ends are adjacent to the walls of the engine cylinder when the piston and connecting rod are at the inner end of their stroke. A lateral orifice to the reservoir B, closed by a spring-pressed ball, is provided for charging the reservoir in known manner by means of an oil squirt. The action of the lubricating device is as follows: An initial charge of oil is given to partly fill the reservoirs, and during the running of the engine the oil surges to and fro in the reservoir and is alternately flung into the mouth of the pipes E and F, and is thus conveyed to the bearings A2, A3. While the oil thus leaves the reservoir, a fresh supply enters by the pipe D by way of the pressure-fed bearing A2. As the reservoirs fill, oil enters into the chamber G, and from thence by pressure, momentum or surging action of the oil in the chamber G, is delivered into the conduits, H, H1, and discharged upon the walls of the engine cylinder. (*Sealed.*)

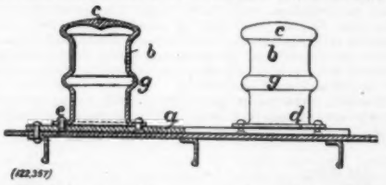
122,772. Wolseley Motors, Limited, Birmingham, and E. Reeve, Birmingham. Internal-Combustion Engines. (2 *Figs.*) May 30, 1918.—This invention has for its object improved means whereby heat may be rapidly conducted from any part of a cylinder barrel or liner of an internal-combustion engine and diffused into the atmosphere. The invention consists in covering a cylinder barrel or liner of good wearing material with a metallic envelope or layer which has high heat conductivity, combined preferably with high specific heat, in such manner as to ensure adhesion or molecular contact between the surface of the barrel or liner and the envelope or layer, and to cover this envelope or layer with a medium which is well adapted to take up



the heat from the envelope or layer and diffuse it into the atmosphere. Referring to Fig. 1, *a*, a^1 is the cylinder barrel or liner, *b*, b^1, the envelope or layer of high heat conductively, combined preferably with high specific heat, and *c*, c^1 is the covering envelope or layer of metal or metallic alloy which readily takes up and diffuses the heat, this envelope or layer being formed, as shown, with gills for radiating heat into the atmosphere. Referring now to Fig. 2, *a*, a^1 and *b*, b^1 correspond, respectively, to the parts similarly lettered in Fig. 1, and *d*, d^1 is a water jacket which surrounds and passes over the envelope or layer *b*, b^1, the water in the jacket portion *d* coming into direct contact with the exterior surface of the portion *b* of the envelope or layer *b*, b^1. (*Sealed.*)

SHIPS AND NAUTICAL APPLIANCES.

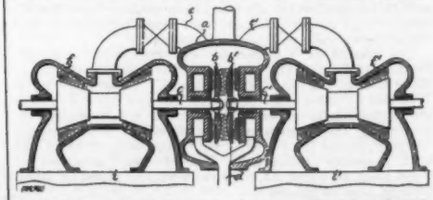
122,357. A Simpson, Newport, Mon. Bollards or Mooring Bitts. (3 *Figs.*) June 15, 1918.—Bollards or mooring bitts constructed, according to the present invention, comprise a bedplate which may be made of steel, and to which is secured one, two or more hollow posts made from steel tube, which is formed to the proper shape at the upper end, the other end being provided with a flange, which may be formed out of the solid. *a* is a steel bedplate and *b*, *b*, two hollow steel posts stamped or



forged at their upper ends as shown at *c*, and formed with a flange *d* at their lower ends, through the intermediary of which they are secured to the bedplate *a* by means of rivets. The flanges *d* may be made separate and be secured to the posts, and after being attached to the bedplate, they may be caulked to the same. The posts may be provided with one or more intermediate flanges *g* made integral therewith, or separate therefrom and attached thereto, or such intermediate flanges may be dispensed with. (*Sealed.*)

STEAM ENGINES, BOILERS, EVAPORATORS, &c.

122,761. The Brush Electrical Engineering Company, Limited, London. (*Aktiebolaget Ljungströms Angturbin, Stockholm, Sweden*). **Radial-Flow Turbines.** (1 *Fig.*) May 8, 1918.—This invention relates to improvements in radial-flow turbines. According to the present invention, there is combined with the shaft or shafts of a radial-flow turbine, either of the single rotation type or of the double-rotation type, an axial-flow turbine or turbines essentially of the duplex-flow type, and which in the case of more than one may also be arranged at each side of the radial-flow turbine, whereby the production of a larger and more powerful turbine is possible, since after leaving the radial-flow



turbine, the motive fluid acts upon an increased number of axial-flow blade systems, which render it more easy to utilise large quantities of high-pressure motive fluid. *a* is a radial-flow turbine of the double-rotation type, that is to say, it is provided with two turbine discs *b*, b^1, together with the shafts *c*, c^1, belonging thereto, respectively; *d* is an inlet for high-pressure steam and *e*, e^1, two outlets for the steam which passes out from the radial-flow turbine and is as yet but partially expanded; *f*, f^1, designate two axial-flow turbines of the duplex-flow type, constructed so that the outlets *e*, e^1, respectively, open out in the centre thereof, after which the steam is divided into two parts, one flowing to the right and the other to the left through the axial vane systems. The outlets open out into the respective condensers *i* and i^1. (*Accepted February* 12, 1919.)